

BBC **NUCLEAR FUSION:** THE RACE FOR UNLIMITED POWER

Science Focus

Reasons why
PLUTO SHOULD BE A PLANET

Are our
HOMES TOO CLEAN?

Why we need a
HYDROGEN ENERGY NETWORK

DUNE

ALIEN WORLDS, SPACE COLONIES AND SUPERHUMANS

A deep dive into the ideas behind the sci-fi event of the decade



IN THIS ISSUE

Ecology

Insects are disappearing in their millions. Can we save them?

Health

Michael Mosley on tracking your fart rate

Physics

A visitor's guide to Earth's magnetic core



This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And for so many survivors the road to recovery is still long and desperately lonely. If you or someone you love has been affected by stroke – you'll know just what that means.

But it doesn't have to be like this. You can change the story, just like Sylvia did, with a gift in your Will. All it takes is a promise.

You can promise future generations a world where researchers discover new treatments and surgeries and every single stroke survivor has the best care, rehabilitation and support network possible, to help them rebuild their lives.

Big or small, every legacy gift left to the Stroke Association will make a difference to stroke survivors and their families.

Find out how by calling **020 7566 1505**
or email **legacy@stroke.org.uk**
or visit **stroke.org.uk/legacy**

Rebuilding lives after stroke

The Stroke Association is registered as a charity in England and Wales (No 211015) and in Scotland (SC037789). Also registered in the Isle of Man (No. 945) and Jersey (NPO 369), and operating as a charity in Northern Ireland.

Stroke
Association



Do butterflies retain their caterpillar memories?
→p79

FROM THE EDITOR



I have to admit science fiction novels are where my love of science really started. As a teenager, William Gibson, Douglas Adams, Ursula K Le Guin and a dozen other authors got me more excited about science and technology than any non-fiction book ever could. And I've got a hunch that many of you might feel the same way.

That's why for this issue we've decided to dive into what looks to be the science fiction event of the decade: *Dune*. Directed by Denis Villeneuve, it is returning to the silver screen in October. This is exciting for two reasons. First, Villeneuve's track record with *Arrival* and *Blade Runner 2049* demonstrates he's something of a maestro when it comes to taking science fiction to the movies. And second, *Dune*, more than 50 years after it was first published, is a story that speaks to the issues of our time. There's a planet with a fiercely hot climate, being stripped of its natural resources by imperialistic powers that have bled their own planets dry. Of course, here in the real world we don't yet have giant worms to contend with, but give it time.

If you head over to p50 you'll discover that we've spoken to prolific sci-fi author Stephen Baxter to find out why *Dune* matters, we've dived into the science propping up the world of *Dune* itself and we've spoken to the film's designer to discover how he realised Frank Herbert's universe on the big screen.

Enjoy the issue!

Daniel Bennett

Daniel Bennett, Editor

WANT MORE? FOLLOW SCIENCEFOCUS ON FACEBOOK TWITTER PINTEREST INSTAGRAM

ON THE BBC THIS MONTH...

Nature And Us
What can history's greatest artworks reveal about the state of the Earth? This new series, presented by James Fox (pictured) explores our relationship with the natural world, as told by prehistoric cave paintings through to modern art.
BBC Four
Available from 11 October

Bad People
In the new series of this podcast, criminal psychologist Dr Julia Shaw and comedian Sofie Hagen are back to cast a forensic eye over some of the most shocking, intriguing and unimaginably criminal acts.
BBC Sounds
Released throughout October

The Life Scientific

Prof Jim Al-Khalili is joined by a fantastic panel of guests for the 10th anniversary of *The Life Scientific*. Paul Nurse, Ottoline Leyser, Christopher Jackson and Hannah Fry (pictured) are just some of the experts joining him for the decade's celebration.
BBC Radio 4
9am, 12 October

CONTRIBUTORS



DR PAUL BYRNE

As we close in on a so-called Planet Nine, planetary scientist Paul makes a convincing case for Pluto to reclaim that title. →p24



DR JULIA SHAW

Between the internet horror stories and the rise of social media, it feels as though narcissism is on the rise. Criminal psychologist Julia examines the social psychology. →p32



PROF DAVE GOULSON

Almost every ecosystem on the planet depends on insects, but their numbers are dwindling. Insect expert Dave tell us what might happen next. →p68



ANDY RIDGWAY

Every week, we find out more about how helpful microbes are to our health. Science writer Andy discovers how we can give these old friends a hand in our homes. →p72

CONTACT US

➔ Advertising

daniel.long@immediate.co.uk
0117 300 8287

➔ Letters for publication

reply@sciencefocus.com

➔ Editorial enquiries

editorialenquiries@sciencefocus.com
0117 300 8755

➔ Subscriptions

buysubscriptions.com/contactus
03330 162 113*

➔ Other contacts

sciencefocus.com/contact

CONTENTS

REGULARS

06 EYE OPENER

Incredible images from around the world.

10 CONVERSATION

See what's landed in our inbox this month.

13 DISCOVERIES

This month's science news: lab-grown mini brains mimic features of Parkinson's; substances in berries, wine and chocolate could lower your blood pressure and boost your microbiome; *T. rex* was a picky eater; alien life could thrive on newly discovered water worlds; Pluto is a planet. Get over it.

28 REALITY CHECK

The science behind the headlines. Hydrogen power: will it help us get to net-zero carbon? Loneliness: is it inevitable in a modern world? More me, now: is narcissism on the rise?

40 SUBSCRIBE TODAY!



Save 40% on the shop price when you subscribe to BBC Science Focus today!

34 INNOVATIONS

The latest news from the world of technology and gadgets.

65 MICHAEL MOSLEY

The Mediterranean diet is an incredibly healthy way to eat, but it can have some unwanted, gassy side effects.

66 ALEKS KROTOSKI

Why the internet is no substitute for traditions, rituals and folk wisdom.

79 Q&A

Our experts answer this month's mind-bending questions. Do butterflies retain their caterpillar memories? What does a comet smell like? Why do people believe in conspiracy theories? Is pink a real colour? Does an apple a day keep the doctor away? Does our Solar System have a wall? Do animals give each other names?

88 CROSSWORD

Get your grey matter churning with our tricky cryptic crossword.

88 NEXT MONTH

See what's in store for you in the next issue of BBC Science Focus.

90 POPCORN SCIENCE

Could we ever regenerate like Doctor Who? We talk to molecular biologist Alejandro Sánchez Alvarado to find out.

22 DISCOVERIES



Take a sneak peek at some of the stunning images from the Bird Photographer of the Year awards.

32 REALITY CHECK



Are we getting more narcissistic, and is social media to blame for the me, me, me crowd?

50 THE SCIENCE OF DUNE



FEATURES

42 FUSION'S TIME TO SHINE

The 'holy grail' of energy has eluded scientists for decades, but could a bright future be on the horizon?

50 THE SCIENCE OF DUNE

One of the decade's most-anticipated sci-fi films hits the cinemas in October. We delve into the science, ideas and history behind it. PLUS: we interview *Dune*'s production designer, Patrice Vermette.

68 THE INSECT APOCALYPSE

Prof Dave Goulson, author of *Silent Earth*, tells us why insects are in decline and how we can help our six-legged friends.

72 GIVE YOUR HOME THE PROBIOTIC MAKEOVER

Should we make our homes and cities more hospitable to beneficial microbes?

38 IDEAS WE LIKE...

As journos, our desks and drawers are a graveyard of used notebooks, paper and chewed pens. We'd quite like to attempt to streamline our lives with this paper-like e-ink tablet.

72

GIVE YOUR HOME THE PROBIOTIC MAKEOVER**68 PROF DAVE GOULSON**

“THERE WAS A TIME WHERE THE WHOLE FRONT OF THE CAR WAS THIS MASS OF DRIED, SPLATTERED INSECT GUTS. AND IT JUST DOESN'T HAPPEN AT ALL ANY MORE”

WANT MORE?

Don't forget that *BBC Science Focus* is also available on all major digital platforms. We have versions for Android, Kindle Fire and Kindle e-reader, as well as an iOS app for the iPad and iPhone.



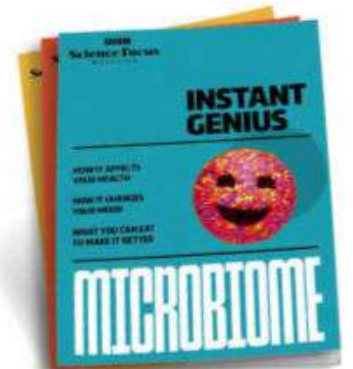
Can't wait until next month to get your fix of science and tech? Our website is packed with news, articles and Q&As to keep your brain satisfied.

sciencefocus.com

**LUNCHTIME GENIUS**

A DAILY DOSE OF MENTAL REFRESHMENT DELIVERED STRAIGHT TO YOUR INBOX

Sign up to discover the latest news, views and breakthroughs from the *BBC Science Focus* team
www.sciencefocus.com/newsletter



PLUS, A FREE MINI-GUIDE EVERY WEEK

A collection of the most important ideas in science and technology today. Discover the fundamentals of science, alongside some of the most exciting research in the world.



EYE OPENER

That sinking feline

MAASAI MARA, KENYA

When photographer Buddhilini de Soyza stood on the side of Talek River in Kenya, she saw across the torrential waters, on the opposite bank, a group of five male cheetahs.

Called Tano Bora or 'the magnificent five' in Maasai, the group are unusual: cheetahs tend to be solitary.

In January 2020, as the river and nearby savannah were overcome by rain and flooding, the Tano Bora saw their prey on the other side of the Talek.

"It took them hours to find a place to cross," says de Soyza. "A couple of times the lead cheetah waded into the river, only to turn back." Then, suddenly, he jumped in. His group slowly followed, until they were swimming towards de Soyza. To her relief, they all emerged from the river.

"The Maasai elders had never seen floods like this before. The rain was likely due to climate change. If we don't take mitigating steps now, such scenarios become another threat to animals like these."

BUDDHILINI DE SOYZA/WILDLIFE PHOTOGRAPHER OF THE YEAR

VISIT US FOR MORE AMAZING IMAGES:

 SCIENCEFOCUS

 BBCSCIENCEFOCUS









EYE OPENER

Eye on the storm

LOUISIANA, USA

One of the most intense hurricanes to hit the US state of Louisiana could be seen from the International Space Station in August.

The storm, named Hurricane Ida, caused rivers to breach their banks and power grids to fail. It also affected the northeastern US, with underground living spaces in New York flooding within minutes. A total of 112 deaths have so far been connected to Ida.

"Aside from being strong and rapidly intensifying, Ida impacted Louisiana in an already historically wet year," explains Prof Paul Miller, a coastal meteorologist at Louisiana State University. "Ida's rain fell on soils that had already absorbed a lot of water, increasing the flood risk."

Big cities have more paved surfaces, preventing rain from being absorbed, says Miller. The flooding that occurs after intense rainfall is exacerbated, because the water is channelled into streams and low-lying areas to result in rapidly rising levels.

NASA/ESA

VISIT US FOR MORE AMAZING IMAGES:

 SCIENCEFOCUS

 BBCSCIENCEFOCUS

CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND BBC SCIENCE FOCUS



reply@sciencefocus.com



BBC Science Focus, Eagle House,
Bristol, BS1 4ST



@sciencefocus

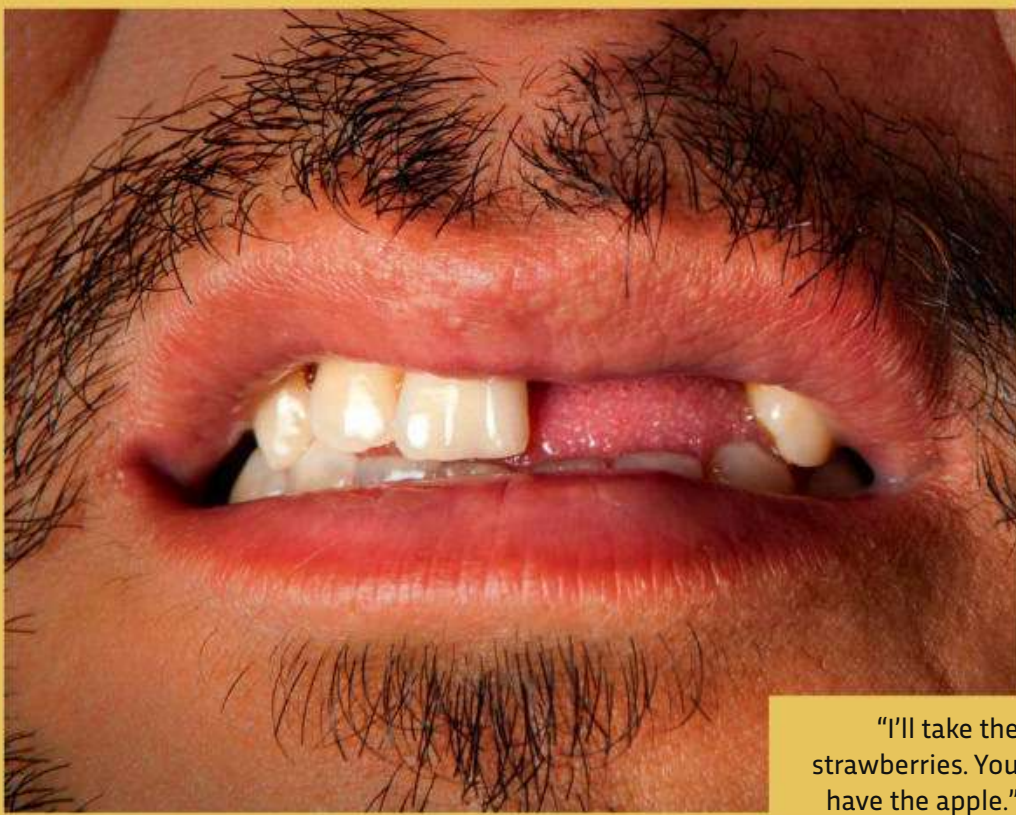


www.facebook.com/sciencefocus



@bbcsciencefocus

LETTER OF THE MONTH



"I'll take the strawberries. You have the apple."

Microbiomes and missing gnashers

In August's issue you reported that Dr Bei Wu and colleagues had found a link between tooth loss and declining cognitive function (p20), speculating that difficulty chewing leads to nutritional deficiencies in the brain.

There may be an additional factor to consider: the gut-brain axis. Without dentures, people may avoid foods that require considerable chewing, such as nuts or high-fibre fruits and vegetables. As these foods aid intestinal bacteria, which play a key role in the gut-brain axis, this would ultimately affect behaviour and cognition.

It would be interesting to analyse the participants' microbiome and, perhaps, monitor how the results are affected by introducing foods that benefit the gut.

Georgina Hawkins (age 14)

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **bundle of kids' science books from Usborne** – just the thing for curious young minds. The prize includes *100 Things To Know About The Human Body*, *The Amazing Discoveries Of 100 Brilliant Scientists*, *Fold-Out Solar System*, *Book Of The Brain And How It Works* and *Science Scribble Book*. Homework will be a breeze! **usborne.com**



Up, up and aboard!

A very interesting article on the potential for using airships to transport cargo and passengers (July, p37). But one thing proponents of airships that don't land [such as those proposed by French company Flying Whale] seem to ignore is how they'll get the passengers on and off the airship.

One way might be to use a modified helicopter with the rotors on the bottom and a hook on top so the helicopter pilot could simply 'hook up' while passenger boarded and disembarked. Granted the helicopter couldn't land like conventional choppers – perhaps it could hang from the hook in the hangar while it waits for the batch of passengers to shuttle to the airship.

C Henry Depew

Record (and rule) breakers

I disagree that there's a limit where Olympic sports' records can no longer be broken (Summer, p81). Human DNA modifications can adapt the body to make athletes run faster and jump higher. It'll only be a matter of time before it's tried and succeeds.

Gerald Klaffke



Cranes work for loading cargo onto airships that don't land, but passengers may prefer other options



“IS DIE HARD A CHRISTMAS FILM? (YES.) DOES PINEAPPLE BELONG ON PIZZA? (ALSO YES.) IS PLUTO A PLANET? I SAY THAT IT IS. BUT IT ISN'T A VIEW THAT'S UNIVERSALLY HELD”

DR PAUL BYRNE, P24



Could genetic modification help athletes set new records? Only if we rewrite the rules of sport

You may be right, Gerald, but genetic modification of athletes – or ‘gene doping’ – is currently banned by the World Anti-Doping Agency, so any new records set by GM athletes wouldn’t be ratified (assuming the athletes could be confirmed to have doped).

Daniel Bennett, Editor

Siri, why are my biscuits stale?

I did laugh at the idea of a smart house (July, p68). I can just imagine the disaster of all the hooked up appliances: food spoils because of an error in the refrigerator’s connection, you sleep late because of an error in the clock’s programming, the auto-drive car crashes into your neighbour’s house...

Robert Caldwell

Location-based faith

Prof Linda Woodhead refers to ‘confident atheists’ as being a small group in the UK

(Summer, p38). In my country, the US – The Land of Guns and Bibles – we’re an even smaller minority. My favourite question to a ‘good Christian’ here is: do you realise that, if you had been born in Iran, you would be Muslim? Your article points out the familial influence on religiosity; geography’s role is even stronger.

RC Gibson

21 again?

As an 87-year-old subscriber to *BBC Science Focus*, I read with apprehension Keith Riley’s letter claiming that an ageing population was the cause of population growth (September, p5).

Maybe a euthanasian cap on age would become the solution to this problem? As I don’t intend to shuffle off this mortal coil just yet I reserve my prerogative to lie about my age if this was to happen!

Rose Marie Shaw

THE TEAM

EDITORIAL

Editor Daniel Bennett

Managing editor Alice Lipscombe-Southwell

Commissioning editor Jason Goodyer

Editorial assistant Amy Barrett

Online assistant Sara Rigby

ART

Art editor Joe Eden

Picture editor James Cutmore

CONTRIBUTORS

Robert Banino, Nisha Beerjeraz, Peter J Bentley, Steve Boswell, Dean Burnett, Jon Butterworth, Paul Byrne, Emma Byrne, Marcus Chown, Adam Gale, Alastair Gunn, Christian Jarrett, Stephen Kelly, Aleks Krotoski, Nish Manek, Michael Mosley, Stephanie Organ, Paul Parsons, Helen Pilcher, Andy Potts, Andy Ridgway, Julia Shaw, Maxim Usik, Luis Villazon.

ADVERTISING & MARKETING

Group advertising manager Gino De Antonis

Business development manager Dan Long
daniel.long@immediate.co.uk

Newstrade manager Helen Seymour

Subscriptions director Jacky Perales-Morris

Direct marketing manager Kellie Lane

MOBILE

Head of apps and digital edition marketing
Mark Summerton

INSERTS

Laurence Robertson 00353 876 902208

LICENSING & SYNDICATION

Director of licensing and syndication Tim Hudson

International partners manager Anna Brown

PRODUCTION

Production director Sarah Powell

Production coordinator Georgia Tolley

Ad services manager Paul Thornton

Ad designer Julia Young

PUBLISHING

Publisher Andrew Davies

Group managing director Andy Marshall

CEO Tom Bureau

BBC STUDIOS, UK PUBLISHING

Chair, editorial review boards Nicholas Brett

Managing director, consumer products and licensing
Stephen Davies

Director, magazines and consumer products
Mandy Thwaites

Compliance manager Cameron McEwan

UK publishing coordinator Eva Abramik

Contact UK.Publishing@bbc.com

www.bbcstudios.com

EDITORIAL COMPLAINTS

editorialcomplaints@immediate.co.uk

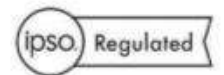
ANNUAL SUBSCRIPTION RATES (INC P&P):

UK/BFPO £77; Europe & Eire £92.54;

Rest of World £102.90.



Audit Bureau of Circulations
45,132 (combined, Jan-Dec 2020)



BBC Science Focus Magazine is published by Immediate Media Company London Limited under licence from BBC Studios who help fund new BBC programmes.

© Immediate Media Co Bristol Ltd 2021. All rights reserved. Printed by William Gibbons Ltd.

Immediate Media Co Bristol Ltd accepts no responsibility in respect of products or services obtained through advertisements carried in this magazine.



When you have finished with this magazine please recycle it.

Mapping a route to success

This is Professor Greg Hannon. He's pioneering a new method of investigating tumours by mapping them with virtual reality.

Professor Greg Hannon has four children, four goats, three dogs, 18 chickens and a cat. As well as looking after his family and animals, he's also helping to fight cancer. Professor Hannon is leader of the Cancer Grand Challenges IMAXT team. IMAXT's aim: to create 3D maps of tumours, which can be explored in virtual reality, to guide oncologists and people with cancer in treatment decisions.

"The programme was born out of my exposure a number of years ago to work done by neuroscientists at Cold Spring Harbour, in New York, particularly those looking at structures within the brain. This made me think that we could do the same thing in cancer biology to start to understand the 3D arrangement of cells in tumours," says Professor Hannon.

In 2017, Professor Hannon and the global team of medics, biologists, engineers, programmers and astronomers behind IMAXT secured £20m funding after impressing the Cancer Grand Challenges panel of eminent scientists with their proposal to create virtual reality 3D maps of tumours. Since then, the IMAXT team has made remarkable progress, building completely new technologies that reveal important information about cancer biology and provide

new clues about cancer prevention and treatment.

"Our programme relies on techniques that didn't exist, so we built them," says Professor Hannon. "People told us it would be impossible and yet here we are, using these new techniques."

"Our initial goal is to have this as a research tool, to allow us to interrogate tumours in a way that was previously impossible. But we certainly see that this is potentially a very powerful tool for everyone to understand more about cancer, from university students to trainee doctors and most importantly patients. Our long-term goal is to see this used in some way in the clinic."

Professor Hannon is certain that what he and the IMAXT team have achieved wouldn't have been possible without Cancer Research UK and the help, such as Gifts in Wills, of its many generous supporters. Gifts in Wills fund a third of Cancer Research UK's research. "This kind of huge global effort couldn't happen without Cancer Research UK having the bravery to invest on that scale," he says.

"I'm always saying that funding on this scale is a privilege, and that we should be using it to drive innovation and tackle cancer's toughest challenges in new ways."



How a gift in your will can help

In the last 40 years, Cancer Research UK has been at the heart of progress that has doubled cancer survival in the UK. One of the best ways to ensure that progress can continue is by leaving a gift in your Will. Gifts in Wills enable Cancer Research UK to plan for the future, so that the charity can fund researchers who can make the breakthroughs needed to beat cancer for future generations. Ordering your free Gifts in Wills Guide gives you access to our Free Will Service, plus information on how to make a pledge, the types of gift you can pledge and the impact they make.



Registered with
FUNDRAISING
REGULATOR

Order your free Gifts in Wills Guide today. Visit cruk.org/pledge or call **0800 077 6644**



CANCER
RESEARCH
UK

Together we will beat cancer



WINE AND TEA

Flavonoid-rich foods improve gut bacteria **p16**

T. REXTASTE

Giant predator may have been a picky eater **p17**

IMPROVING WITH AGE

Risk of genetic diseases drops as you grow older **p18**

TRIPLE ESPRESSO!

Three cups of coffee a day may lower risk of heart disease **p19**

DISCOVERIES

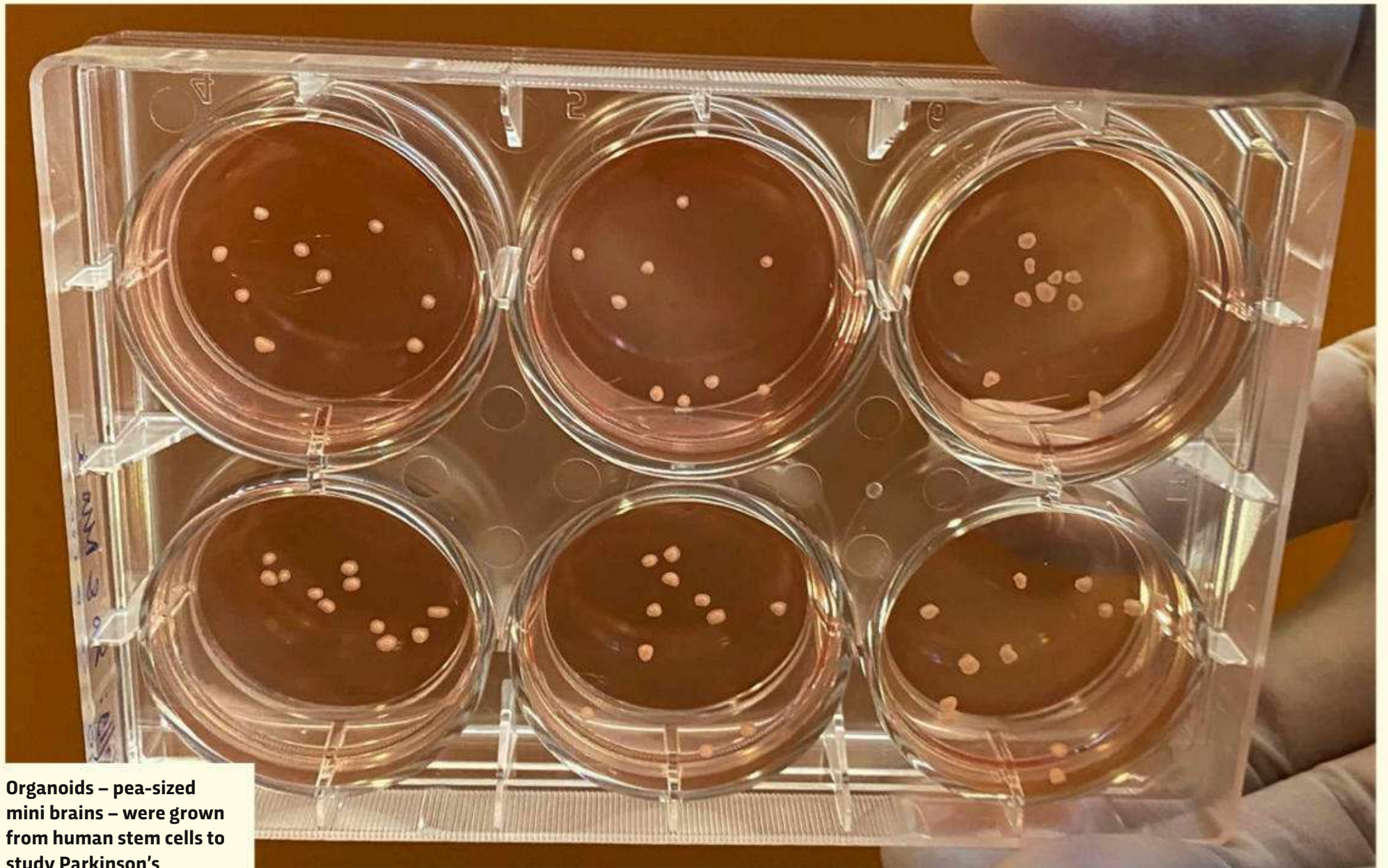
NEUROLOGY

LAB-GROWN MINI BRAINS THAT MIMIC FEATURES OF PARKINSON'S CREATED FOR THE FIRST TIME

The breakthrough could lead to revolutionary new treatments

SCIENCE PHOTO LIBRARY

Rhino relations Studying the rhino family tree may help save the animals from extinction **p20** **ET's ETA** Signs of alien life expected to be found within three years **p21** **Pluto is a planet** So says planetary scientist Paul Byrne **p24**



Organoids – pea-sized mini brains – were grown from human stem cells to study Parkinson's

Each year more than 17,000 people aged 45 and over are diagnosed with Parkinson's disease in the UK. Worldwide, neurological disorders are the leading cause of disability, and Parkinson's disease is the fastest growing among them.

Parkinson's is a progressive neurological disease that affects a person's nerve cells, leading them to suffer from tremors, muscle stiffness and slowness of movement. There is currently no known cure.

Much of the previous research on Parkinson's has relied on the use of mice, which doesn't allow scientists to study all of the effects of the disease.

Now, researchers from the Agency for Science, Technology And Research (A*STAR)'s Genome Institute of Singapore (GIS), the National Neuroscience Institute (NNI) and Duke-NUS Medical School have discovered a way to produce mini brains that mimic the physiological effects of Parkinson's.

"Recreating models of Parkinson's disease in animal models is hard as these don't show the progressive

"It's a major challenge to extend healthy living years"

and selective loss of [the] neurons that produce the neurotransmitter dopamine, a major feature of Parkinson's disease," said Prof Ng Huck Hui, senior group leader at GIS and a senior co-author of the study.

"Another limitation is that experimental mouse models of Parkinson's disease don't develop characteristic clumps of proteins called Lewy bodies, which are often seen in the brain cells of people with Parkinson's disease, and a type of progressive dementia known as Lewy body dementia."

The team grew the small, pea-sized mini brains by coaxing human stem

cells to develop into the bundles of neurons and other cells found in the human brain.

By manipulating the DNA of the developing stem cells to match genetic risk factors found in patients with Parkinson's disease, the researchers were able to grow organoids with neurons that showed both Lewy bodies and the progressive loss of dopamine-producing neurons.

The researchers have now begun to work on using the organoids to study how the Lewy bodies progress, and have also started testing drugs to slow down, or possibly even stop, the advancement of the disease.

"It's a major challenge to extend healthy living years in an ageing global population, whose physical and cognitive performance often declines due to neurodegenerative disorders," said Prof Tan Eng King, deputy medical director of academic affairs at NNI, and senior co-author of the study.

"This discovery provides insights and a 'humanised' disease model that can facilitate drug testing against Parkinson's disease and dementia."

MEDICINE

Viruses could help us win the fight against antibiotic-resistant infections

A virus called 'Muddy' helped treat abscess-causing infection in zebrafish

Since the discovery of penicillin by Alexander Fleming in 1928, bacteria have constantly evolved new ways to resist the effects of antibiotics.

Currently more than 50,000 people die in Europe and the US every year from infections that don't respond to conventional antibiotic treatments. If current trends continue, all of our antibiotic medicines could become ineffective within the next few decades.

One way of potentially countering this trend is to use bacteriophages – naturally occurring viruses that are capable of killing bacteria.

Now, a team of researchers from the Université de Montpellier, France, and the University of Pittsburgh, USA, have discovered that combining bacteriophages with conventional antibiotic treatments

could make them even more effective at slaying bacteria.

The team decided to focus their efforts on *Mycobacterium abscessus*, a relative of the bacteria that cause tuberculosis and leprosy, and is resistant to many standard antibiotics. As *M. abscessus* is particularly dangerous to patients with cystic fibrosis, the researchers took zebrafish that had been bred to carry the key genetic mutation that causes cystic fibrosis, then infected them with *M. abscessus*. They then tested the ability of a number of bacteriophages to combat the infection.

First, the team screened 10,000 bacteriophages, before they found one candidate, which they named 'Muddy', that was capable of efficiently killing *M. abscessus* in a Petri dish. They then infected zebrafish with *M. abscessus* and monitored them for 12 days.

They found that the fish treated with Muddy had much less severe infections and were twice as likely to survive – 40 per cent of them

survived compared to 20 per cent of untreated fish.

They then treated fish with a combination of Muddy and rifabutin, an antibiotic used to treat *M. abscessus* infection that's similar in effectiveness to the Muddy treatment. This time the survival rate rocketed to 70 per cent and the fish suffered far fewer abscesses.

"We need clinical trials, but there will be many other questions to be answered on our way there. And zebrafish provide a very helpful tool for advancing these questions," said Dr Graham Hatfull from the University of Pittsburgh.

"Fish treated with 'Muddy' had less severe infections"

Zebrafish infected with *Mycobacterium abscessus*, shown in red

HEALTH

Compounds found in chocolate and tea promote gut health and lower your blood pressure

Flavonoids, which are found in foods like chocolate, berries and tea, play a key role in heart health

A diet rich in flavonoid compounds is linked to lower blood pressure, according to a new study. The association is partly explained by an improved gut microbiome.

Flavonoids are compounds found in plants. Foods rich in flavonoids include vegetables, fruits such as apples, pears and berries, and chocolate, tea and wine. In the body, they act as antioxidants, and prevent damage to cells. They are broken down by the gut microbiome.

“Our gut microbiome plays a key role in metabolising flavonoids to enhance their cardioprotective effects, and this study provides evidence to suggest these blood-pressure-lowering effects are achievable with simple changes to the daily diet,” said Prof Aedín Cassidy at Queen’s University in Belfast, Northern Ireland, lead investigator of the study.

The World Health Organization lists cardiovascular disease (CVD) as the leading cause of death worldwide in 2019. Previous research has reported differences in the composition of the gut microbiome between those with and without CVD, and that flavonoids may reduce the risk of heart disease.

The team of researchers, based at Queen’s University and Kiel University, Germany, examined the link between eating flavonoids, blood pressure, and the gut microbiome. They studied 904 adults from Germany’s PopGen biobank, 57 per cent of whom were men, and asked them to evaluate their food intake with a self-reported questionnaire. The team also analysed their gut microbiome through bacterial DNA in stool samples, and measured their blood pressure.

In addition, the researchers asked the participants about several other factors, including BMI, family history of CVD, physical activity and medication use. After taking all of these into account, they found that those with the highest intake of flavonoids had lower blood pressure and a greater diversity in their gut microbiome.

Eating 1.6 servings of berries a day reduced systolic blood pressure by 4.1mmHg, while 2.8 glasses of red wine per week brought a reduction of 3.7mmHg.

The team found that up to 15.2 per cent of the reduction in blood pressure could be explained by the increased gut microbiome diversity.

“Our findings indicate future trials should look at participants according to metabolic profile in order to more accurately study the roles of metabolism and the gut microbiome in regulating the effects of flavonoids on blood pressure,” said Cassidy.



Five ways to improve your gut microbiome



Increase your fibre intake

Aim for more than 40g per day – about double what the average person consumes. Wholegrains, pulses and veg are good sources.



Eat a wide variety of fruit and veg

Variety is important, as the chemicals and types of fibre will be different, and each support different microbial species.



Choose food and drinks with high levels of polyphenols

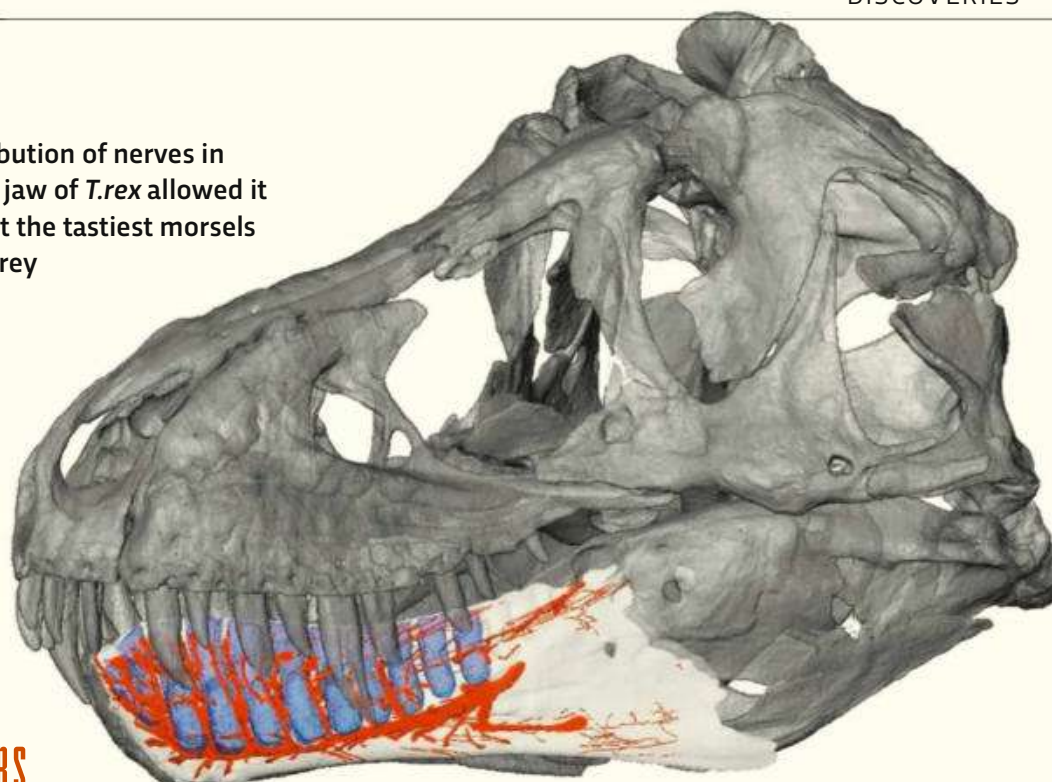
Polyphenols are fuel for microbes. Nuts, seeds, berries, olive oil, coffee and tea are good sources.



Avoid artificial sweeteners such as aspartame

These disrupt the metabolism of microbes and reduce gut diversity.

The distribution of nerves in the lower jaw of *T. rex* allowed it to pick out the tastiest morsels from its prey



DINOSAURS

Tyrannosaurus rex may have been a picky eater

Detailed scans of a *T. rex*'s jaw show it had nerves capable of sensing and selecting the choicest parts of its prey

Just when you thought that the king of the dinosaurs couldn't get any more terrifying, a study by Japanese researchers has found that *T. rex* may have been able to pick out the most desirable, tastiest parts of its freshly killed prey.

A team of researchers based at the Institute of Dinosaur Research in Fukui Prefectural University, Japan, used computed tomography (CT) scanning techniques to reconstruct the complex structure of blood vessels and nerves found in the mandible of a *T. rex* fossil originally unearthed in Hell Creek Formation, Montana.

By comparing their data to scans of other dinosaurs such as *Triceratops*, along with currently living birds and crocodiles, they were able to determine that *T. rex* had nerve sensors in the tip of its jaw that enabled it to more easily detect and select the tastiest morsels.

"*T. rex* was an even more fearsome predator than previously believed," said lead author Dr Soichiro Kawabe. "Our findings show the nerves in the mandible

[lower jaw] of *Tyrannosaurus rex* are more complexly distributed than those of any other dinosaurs studied to date, and comparable to those of modern-day crocodiles and tactile-foraging birds, which have extremely keen senses.

"What this means is that *T. rex* was sensitive to slight differences in material and movement; it indicates the

possibility that it was able to recognise the different parts of its prey and eat them differently depending on the situation," Kawabe added. It's a bit like how a bear might only eat the head of a salmon if it's already full.

The results echo the findings of other studies of theropod dinosaurs, including the skull of *Daspletosaurus*, and the

nerves and blood vessels in the jaw of *Neovenator*. This makes it likely that the facial areas of theropod dinosaurs were highly sensitive, the researchers say.

"This completely changes our perception of *T. rex* as a dinosaur that was insensitive around its mouth, putting everything and anything in, [and] biting at anything and everything, including bones," said Kawabe.

✕
"This completely changes our perception of *T. rex* as a dinosaur"



Stroke animals

Studies have shown that people living with dogs have more microbial diversity.

GETTY IMAGES X4, ALAMY X2, HISTORICAL BIOLOGY

GENETICS

The risk of developing a genetic disease drops off as we age

The finding may enable scientists to predict a person's future risk of disease by analysing their genome

It's widely known that as we age our immune systems become weaker and slower to respond to infection, leaving us at a greater risk of becoming ill. But when it comes to developing genetic diseases, the risk of us getting ill actually wanes with age, a study carried out at the University of Oxford has found.

We each inherit half of our genes from our father and half from our mother. Our genes play a huge role in our appearance and development – from our hair colour to our height – but also influence our risk of developing all manner of diseases such as cancer and heart disease.

By using genomic data taken from 500,000 people and stored in the UK Biobank, the researchers were able to look for the existence of age windows in which we are more likely to develop 24 common diseases linked to our genetics.

They found that while diseases show different risk patterns over the course of a person's life, the genetic risk of developing many diseases,

such as high blood pressure, skin cancer and underactive thyroid, peaks in early life and then drops off as we age.

“Our work shows that the way in which genetics affects your risk of getting a disease changes throughout life,” said study lead Prof Gil McVean. “For many diseases, genetic factors are most important in determining whether you will get a disease early in life, while – as you age – other factors come to dominate risk.”

Currently, the reasons why the risk posed by a person's genes decreases with age are not clear. The researchers suspect that there may be unknown processes at work, such interactions between a person's genes and their environment that lead to disease.

A better understanding of how age impacts a person's risk of developing a disease linked to their genes may help researchers make more accurate predictions about whether an individual will ultimately become sick with that condition.

The risk of developing genetic diseases declines with age

×

“Our genes influence our risk of developing all manner of diseases, such as cancer”





HEALTH

Regularly drinking coffee may help to protect your heart

Drinking three cups of coffee a day is linked to a lower risk of cardiovascular disease and stroke

Whether it's a black Americano, a strong espresso, or a triple venti no foam soy milk latte with an extra shot, drinking your daily cup of Joe may help to lower your risk of stroke and fatal heart disease.

Researchers at the Heart and Vascular Centre, Semmelweis University, Budapest, Hungary, have found that drinking up to three cups of coffee a day may help protect your cardiovascular system.

The team studied data from nearly 500,000 people registered in the UK Biobank with an average age of 56 and no signs of heart disease at the time of recruitment. They divided them into three categories according to their coffee habits – non-drinkers, up to three-cup-a-day drinkers, and more than three-cup-a-day drinkers.

When adjusted for influencing factors such as age, sex, weight, height, physical activity, blood pressure, diabetes, cholesterol, socioeconomic status, and usual intake of alcohol, meat, tea, fruit and vegetables, they found that three-cup-a-day drinkers had a 12 per cent lower risk of death from all causes, a 17 per cent lower risk of death from cardiovascular disease, and a 21 per cent lower risk of stroke.

“To our knowledge, this is the largest study to systematically assess the cardiovascular effects of regular coffee consumption in a population without diagnosed heart disease,” said author Dr Judit Simon.

“Our results suggest that regular coffee consumption is safe, as even high daily intake was not associated with adverse cardiovascular outcomes and all-cause mortality after a follow-up of 10 to 15 years. Moreover, 0.5 to 3 cups of coffee per day was independently associated with lower risks of stroke, death from cardiovascular disease, and death from any cause.”

To further investigate the effect, the researchers used data from more than 30,000 participants in the Biobank who had undergone magnetic resonance imaging (MRI) scans to determine the structure and functioning capacity of their hearts.

“The imaging analysis indicated that compared with participants who did not drink coffee regularly, daily consumers had healthier-sized and better-functioning hearts. This was consistent with reversing the detrimental effects of ageing on the heart,” said Simon. “Our findings suggest that coffee consumption of up to three cups per day is associated with favourable cardiovascular outcomes. While further studies are needed to explain the underlying mechanisms, the observed benefits might be partly explained by positive alterations in cardiac structure and function.”

Indulge in a daily cup of coffee or three to reap health benefits

ZOOLOGY

Study of rhino family tree may help save them from extinction

Rhinoceroses naturally have low genetic diversity. This means we may be able to recover their numbers, despite there being so few of them left

There are currently five species of rhinoceros living on Earth: Indian, Javan, Sumatran, white and black. But piecing together exactly how they are related has proven problematic, thanks to a lack of genetic data.

Now, a study by an international team of researchers has helped to fill the gaps in the rhino evolutionary family tree by analysing and comparing the genomes of all five living species along with the genomes of three extinct species – woolly, Merck’s, and the Siberian unicorn.

“We can now show that the main branch in the rhinoceroses’ tree of life is among geographic regions, Africa versus

Eurasia, and not between the rhinos that have one versus two horns,” said study author Love Dalén of the Centre for Palaeogenetics and the Swedish Museum of Natural History.

“The second important finding is that all rhinoceroses, even the extinct ones, have comparatively low genetic diversity. To some extent, this means that the low genetic diversity we see in present-day rhinos, which are all endangered, is partly a consequence of their biology.”

They found that all eight species showed a slow decrease in population size over the past two million years or had consistently small populations over extended periods of time – this may mean that rhinoceroses are naturally adapted to living in groups with low genetic diversity, the researchers say.

This theory fits with the currently held idea that rhino populations have not accumulated disease-causing genetic mutations over the past 100 years,

allowing them to stay healthy despite inbreeding and low genetic diversity.

The findings also mean that conservation programmes designed to help rhino numbers recover should perhaps switch from focusing on increasing genetic diversity to increasing population size, the researchers say.

The extinct Siberian unicorn, illustrated in the foreground, had its genome compared with modern rhinos



Rhino species alive today Info from WWF

Name	Indian	Sumatran	Javan	White	Black
					
Population	~3,500	<80	75	~18,000	~5,600
Status	Vulnerable	Critically endangered	Critically endangered	Near threatened	Critically endangered
Distribution	Eastern Himalayas, India and Nepal	Borneo and Sumatra	Ujung Kulon National Park, Java	Namibia and coastal East Africa	Namibia and coastal East Africa
Weight	1,800-2,700kg	590-950kg	900-2,250kg	1,350-3,600kg	800-1,350kg

BETH ZAIKEN, AMANDA SMITH/UNIVERSITY OF CAMBRIDGE

Alien life could thrive on newly discovered 'water world' planets

Astronomers say focusing on these "hycean" planets could mean we find alien life in the next two to three years

When hunting for signs of life on other planets, astronomers have typically played it safe. They've looked for Earth-sized planets, with Earth-like surface temperatures, and Earth-like atmospheres.

But now, a team of researchers from the University of Cambridge have identified a new class of habitable planets that could change the game completely. Dubbed 'hycean' planets – a portmanteau of 'hydrogen' and 'ocean' – these newly identified exoplanets are more numerous and easier to spot than Earth-like planets.

According to the researchers, specifically hunting for hycean planets could lead to us discovering biosignatures of life outside our

Solar System within the next two or three years.

"Hycean planets open a whole new avenue in our search for life elsewhere," said study leader Dr Nikku Madhusudhan, from Cambridge's Institute of Astronomy.

"Essentially, when we've been looking for these various molecular signatures, we have been focusing on planets similar to Earth, which is a reasonable place to start. But we think hycean planets offer a better chance of finding several trace biosignatures."

Hycean planets can be up to 2.6 times larger than Earth and have atmospheric temperatures as high as 200°C. However, their oceanic conditions could be similar to Earth's and so could potentially harbour microbial life. A significant proportion of the exoplanets discovered so far fall into this category.

The larger sizes, higher surface temperatures and hydrogen-rich atmospheres of hycean planets also make their atmospheric signatures easier to detect than Earth-like planets.

When looking for signs of life on other planets, astronomers look at so-called biosignatures such as oxygen, ozone, methane and nitrous oxide, which are all present on Earth. There are also a number of other biomarkers, such as methyl chloride and dimethyl sulphide, that could suggest the existence of

life on planets with hydrogen-rich atmospheres where oxygen and ozone may not be as abundant.

"A biosignature detection would transform our understanding of life in the Universe," said Madhusudhan. "We need to be open about where we expect to find life and what form that life could take, as nature continues to surprise us in often unimaginable ways."

The researchers have identified a number of hycean planets between 35 and 150 light-years away that they hope will be prime targets for the next generation of space telescopes, such as the James Webb Space Telescope (JWST), due to be launched later this year.

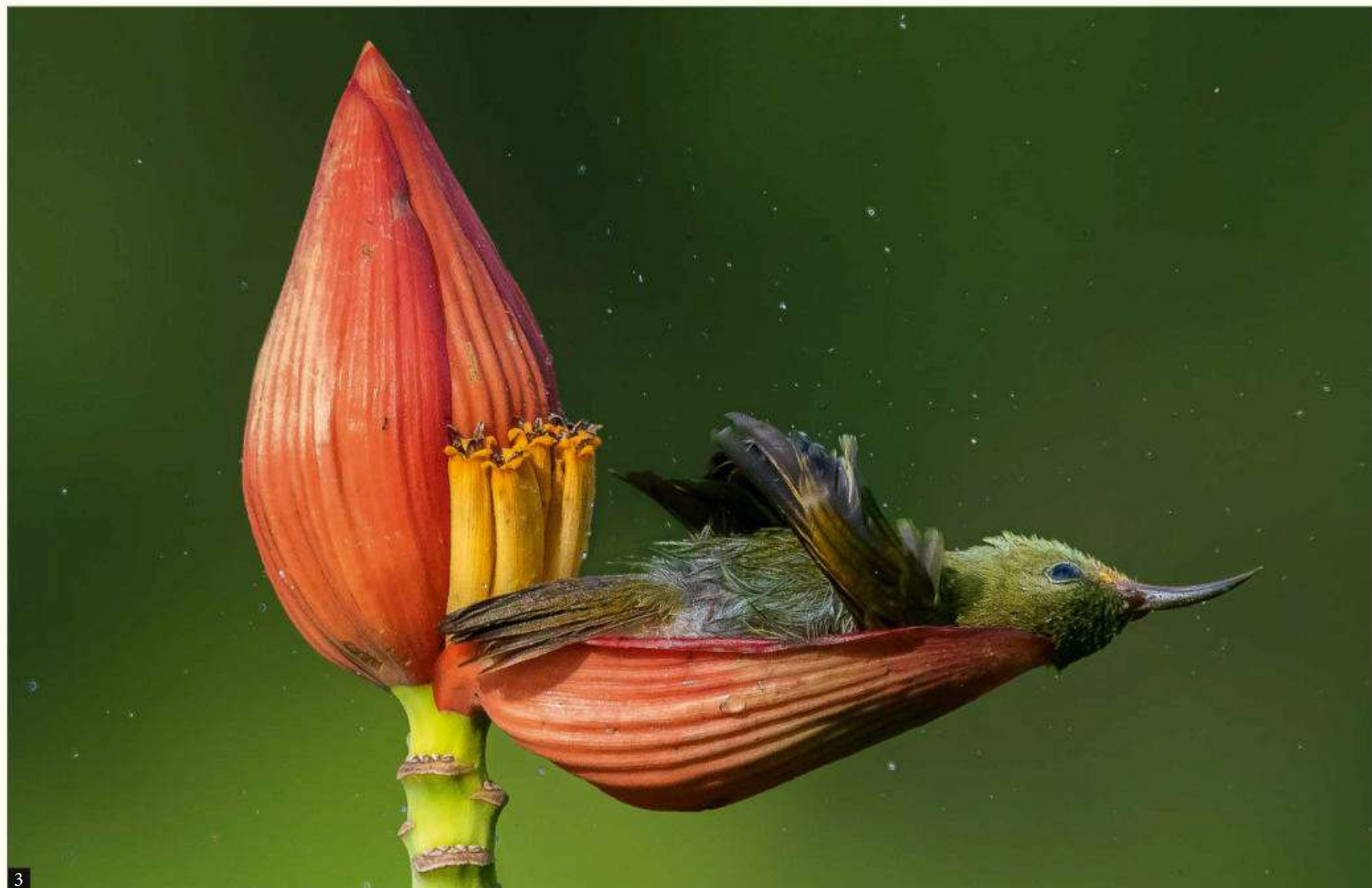
"Hycean planets open a whole new avenue in our search for life elsewhere"



PHOTOGRAPHY

Roadrunner stopped by border wall wins photography award

As photography subjects go, birds are notoriously flighty. So it's not hard to admire the work on show at the Bird Photographer of the Year contest. The winners of the 2021 prize have been announced, narrowed down from a flock of 22,000 entries. See some of the winners on these pages, and explore more incredible entries at birdpoty.com





1. Bronze Award Winner, 9-13 years

by Ian Henderson

A woodpecker finch uses a small twig to fish insects out of a piece of rotten wood in the Galapagos Islands.

2. Bronze Award Winner, 14-17 years

by Daniel Zhang

Although it seems that the toad is jumping into the hamerkop's mouth, the bird is actually throwing its prey around to kill it. The photo was snapped in Zimanga Private Game Reserve, South Africa.

3. Bird Behaviour Winner

by Mousam Ray

A literal bird bath in West Bengal, India. This crimson sunbird makes the most of the banana plant it's lounging in. After drinking nectar from the

flower, it lay back in the rainwater collected in the flower's petal.

4. Overall Winner

by Alejandro Prieto

Beep-beep. This roadrunner stops in its tracks in front of a section of border wall between the US and Mexico in southern Arizona. The 3,000km-long border traverses a range of habitats and this image, the competition's overall winner, illustrates how a wall along it can disrupt the behaviour of local nomadic species.

5. Conservation Winner

by Carla Rhodes

Greater adjutants scavenge for food on a rubbish dump in Deepor Beel in Assam, India. Loss of their natural wetland habitat has forced the birds to look elsewhere for food.



PAUL BYRNE
Planetary scientist

Comment

Pluto is a planet. Get over it

Planetary scientist **Paul Byrne** argues our official definition of what is and isn't a planet is in need of a long-overdue shake-up

There are some topics that elicit strong opinions from people. Is *Die Hard* a Christmas movie? (Yes.) Does pineapple belong on pizza? (Also yes.) Is Pluto a planet? I say that it is. But this isn't a view that's universally held.

Those of us born in the latter part of the 20th Century grew up learning that there are nine planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto, in increasing distance from the Sun. But in 2006, the International Astronomical Union (IAU) – the entity charged with, among other things, deciding what to call stuff in space – held a vote that overnight reduced the number of planets in the Solar System to eight.

From its discovery in 1930 until the 1990s, Pluto was the largest known object in a distant region of the Solar System that came to be called the Kuiper Belt. Soon after Pluto was detected, astronomers conjectured that other similarly sized objects might lurk out there in the far reaches of our planetary system. But the first confirmed detection of another Kuiper Belt object wasn't until 1992, with the discovery of a body eventually called 15760 Albion. Since then, more than 2,000 bodies have been identified in this part of space, with the true quantity of worlds greater than

100km in diameter perhaps numbering in the hundreds of thousands.

And herein lies the problem with Pluto's classification as a planet: if Pluto were to retain its status as a planet, then so too would everything else out in the Kuiper Belt and before we know it, we'd have hundreds of planets. Crazy, right? (Never mind that we have hundreds of countries, thousands of languages and 8.7 million known species of animal.)

So, to avoid cluttering up children's bedroom walls with unreasonably huge posters, the IAU held a vote at its General Assembly in Prague in August 2006 at which it was decreed that a planet must meet three criteria:

1. It orbits the Sun (so sorry, planets ejected from the Solar System or in orbit around other stars, you're out).
2. It has attained hydrostatic equilibrium (that is, its gravity has pulled it into a spherical shape, or close enough).
3. It has "cleared its neighbourhood".

Whereupon Pluto stopped being a 'classical planet' and started being a 'dwarf planet'.

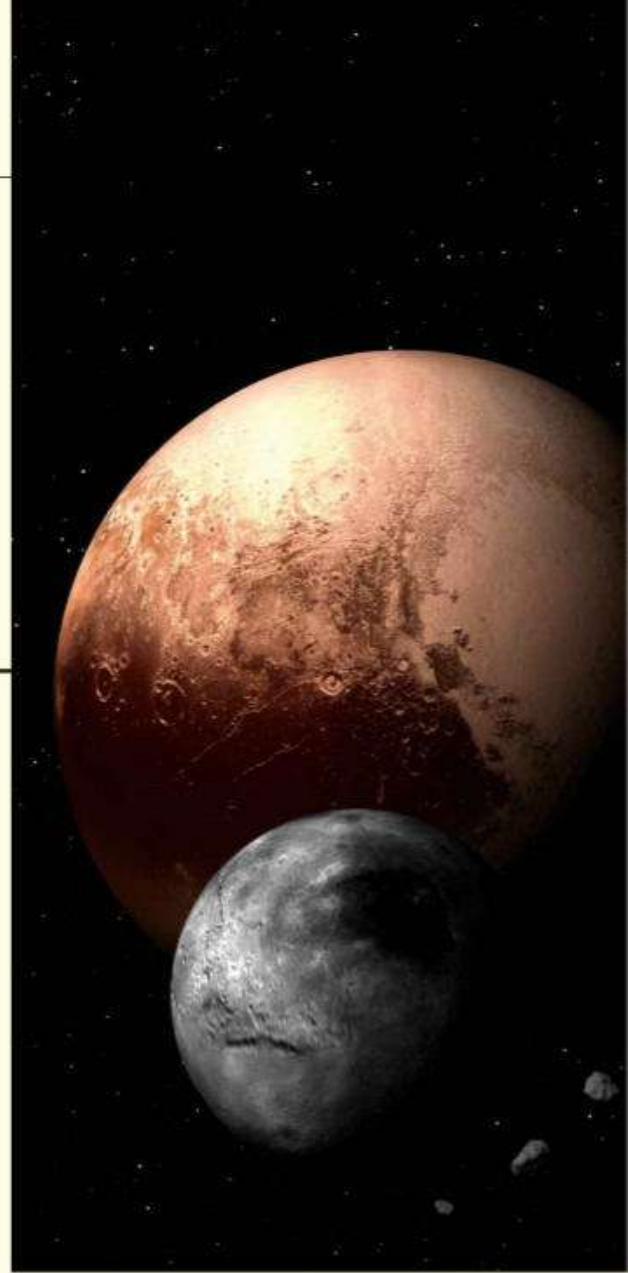
That last criterion states that a planet must be the gravitationally dominant object in the area of space in which it orbits. This rule makes sense for

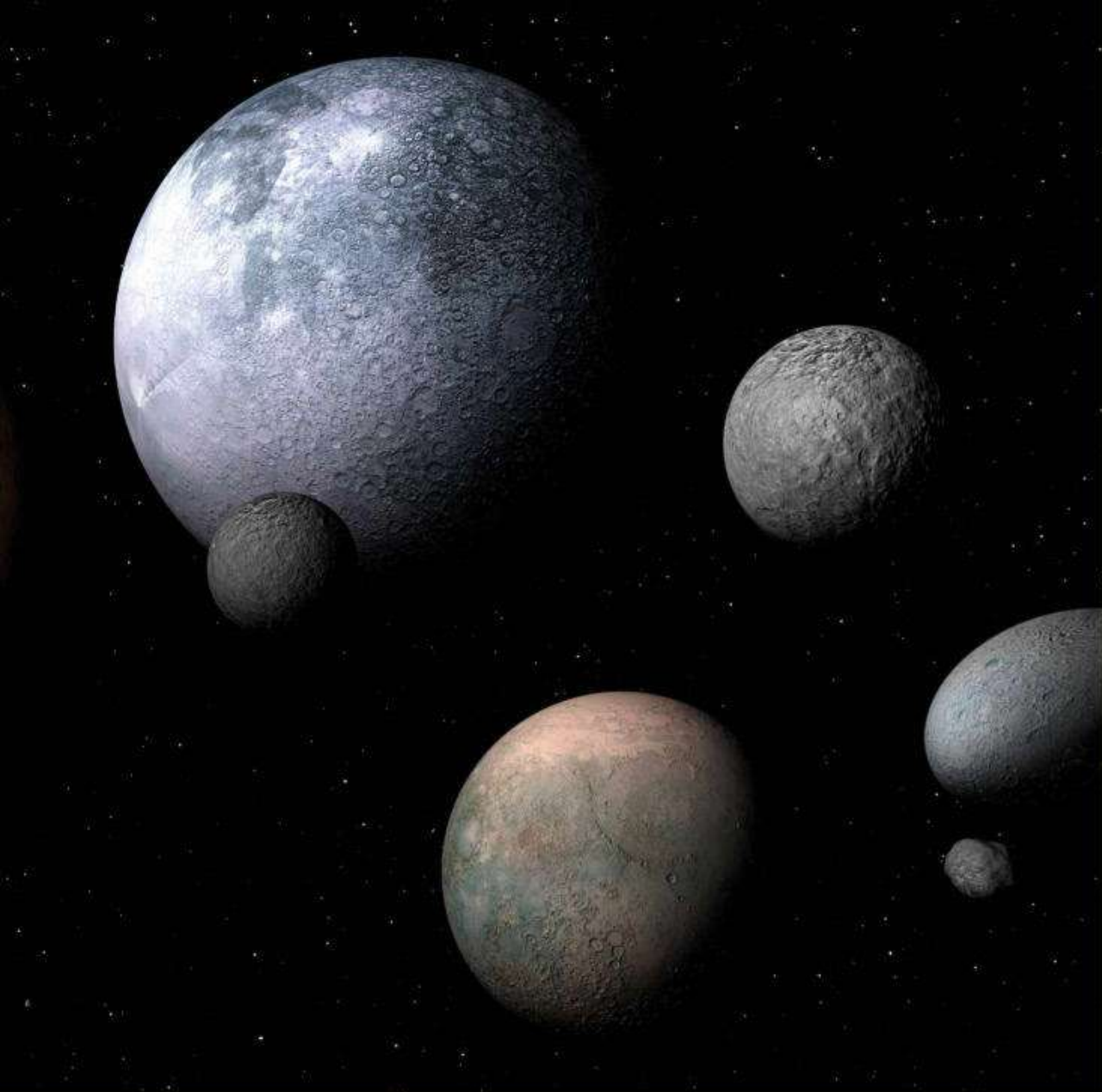
somewhere like Earth, which is far more massive than the Moon and anything else along its orbital path. But out in the Kuiper Belt, where neighbouring bodies are far, far more distant than in the inner Solar System, Earth would not necessarily be able to clear its neighbourhood. In fact, if we were somehow able to drag Earth out past Neptune, our world could become gravitationally dominated by that icy giant and thus lose its own planethood.

LOCATION, NOT CHARACTER

It's this idea of 'neighbourhood clearing' that's the crux of the problem regarding the IAU's definition of a planet. And that's because it's a dynamic criterion: it's a function of where a body is in space and pays no heed to the character of a body beyond the fact that it's big enough to be a ball. It doesn't allow for the geology of a world to be considered.

This argument pre-dates the flyby of Pluto in July 2015 of NASA's New Horizons spacecraft, but the images returned by that spacecraft really help make the case. Pluto is an enigmatic world with towering ice mountains, vast glaciers of nitrogen ice, a tenuous atmosphere, a thick, outer icy carapace and a probably liquid water ocean below, all atop a huge rocky interior. By any geological measure – including





Some dwarf planets (as illustrated here) can have their own moons, but if they can't clear their orbital path they can't be 'classical' planets

“This argument pre-dates the flyby of Pluto in July 2015 of NASA's New Horizons spacecraft, but the images returned by that spacecraft really help make the case”

the fact that there are surface processes acting on Pluto today – Pluto is a planet.

But it's the International Astronomical Union, not the International Geophysical Union. And the people who voted on the new planet classification were overwhelmingly astronomers, even if some proportion were planetary

astronomers. What properties matter to some scientists (where an object is, how massive it is, what its orbit looks like) might be far less important to others. And to those of us who study the surfaces and interiors of bodies across the Solar System, neighbourhood clearing doesn't come close to being important in how we regard them.

THE MORE THE MERRIER

To be fair, this isn't a straightforward issue. Notwithstanding the fact that the IAU definition at present doesn't allow for planets outside the Solar System (the IAU has said it plans to tune up the 'planet' definition to encompass exoplanets, but has yet to do so), nature tends to be more complex than simple categories allow. If we acknowledge Pluto as a planet, then should we consider the Moon a planet? Or Ganymede, Jupiter's largest moon, bigger (though less massive) than Mercury?

As a geologist, my view is: “Yes, why not?” Personally, I don't see any utility in splitting things up into individual categories because the Universe tends not to operate that way. (There's also the fact that Pluto has far more in common with Mars than Mars does with Saturn, say, yet the latter two are indubitably planets.) Several hundred planets? Great! Kids (and I) would recite their

names with the ease with which they (and I) list dinosaurs – of which 700 or so species have been documented.

In short, there's more value in being a lumpner than a splitter.

There's one more aspect to this issue that troubles me and it's the optics of what happened to Pluto. Proponents of the IAU vote argue that Pluto is still a certain type of planet. Yet the IAU definition explicitly excludes Pluto from the list of 'classical' planets to which it once belonged. In other words, the 'dwarf' in 'dwarf planet' is not the same as 'terrestrial' in 'terrestrial planet' (for example, Venus) or 'giant' in 'giant planet' (for example, Uranus). By every measure, even if the IAU didn't use the term, Pluto was demoted.

And even a quick internet search throws up this word. The public perceives what happened to Pluto as it being demoted; shortly after the IAU vote, the American Dialect Society selected 'plutoed' as its Word of the Year, writing: “To 'pluto' is to demote or devalue someone or something, as happened to the former planet Pluto when the General Assembly of the IAU decided Pluto no longer met its definition of a planet.”

Whenever I give a public talk and mention Pluto, the first question I'm asked is whether Pluto is still a planet – not, say, why it's surface looks so damned weird. Fifteen years on, Pluto's demotion gets more attention than the cool things we've learned about it and that's a big science communication fail.

A planet can be whatever we want it to be and there's no reason we can't have hundreds of them in the Solar System. And from this geologist's view, the IAU reclassification of Pluto was a mistake.

PAUL BYRNE

Paul is an associate professor of earth and planetary science at Washington State University in St Louis. His research focuses on what makes planets behave and look the way they do.



CUSTOM BUILT

DESKTOPS & LAPTOPS



CUSTOM BUILT
TO YOUR SPEC



EASY TO USE
CONFIGURATOR



CUSTOM PCS
& LAPTOPS



AWARD-WINNING
SYSTEMS

STUDIO ULTRA CUSTOM DESKTOP



- ▶ Intel® Core™ i7-10700K
- ▶ ASUS® ROG Strix Z590-F Gaming WiFi
- ▶ 32GB CORSAIR VENGEANCE® 3000MHz
- ▶ 8GB NVIDIA GeForce RTX™ 3070
- ▶ 1TB Samsung 970 EVO M.2 NVMe SSD
- ▶ 2TB SEAGATE BarraCuda HDD
- ▶ Genuine Windows 10 Home

This spec from
£2,099.00*



GET A FURTHER **£15 OFF**
WITH THIS EXCLUSIVE VOUCHER

BBF21

CONFIGURE YOURS NOW AT
WWW.PCSPECIALIST.CO.UK

RECOIL SERIES LAPTOP



- ▶ 165Hz QHD Panel
- ▶ 2560 x 1440, sRGB 100%
- ▶ Intel® Core™ or AMD® Ryzen™ CPU
- ▶ GeForce RTX™ 3060 / 3070 / 3080
- ▶ Genuine Windows 10 Home

This spec from
£1,389.99*



FUSION PRO CUSTOM DESKTOP



- ▶ AMD Ryzen 7 5800X
- ▶ ASUS® TUF X570-Plus Gaming
- ▶ 16GB CORSAIR VENGEANCE® 3000MHz
- ▶ 16GB AMD Radeon™ RX 6800 XT
- ▶ 512GB PCS PCIe M.2 SSD
- ▶ Genuine Windows 10 Home

This spec from
£2,170.00*



*Prices are including VAT and are correct at time of printing, but subject to change.
Images are for illustration purposes only, components may differ in aesthetics and brand.



PCSpecialist



@PCSpecialist

REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Blue hydrogen | Loneliness | Narcissism



REVIEW

HYDROGEN POWER: WILL THE GOVERNMENT'S STRATEGY HELP US GET TO NET-ZERO CARBON?

The government plans to provide the UK with low-carbon energy derived from hydrogen. But will it help really us reach our emissions targets?

“Hydrogen can be burned in the same way and produces only water (no CO₂), but you need roughly three times as much to produce the same amount of energy”



Visit the BBC's Reality Check website at bit.ly/reality_check_ or follow them on Twitter @BBCRealityCheck

WHAT IS THE GOVERNMENT'S PLAN?

The main aim of the UK Hydrogen Strategy is to be able to produce five gigawatts (five billion joules per second) of low-carbon power from hydrogen by 2030 – equivalent to the amount of gas used by three million UK households.

The hydrogen could be used in various ways. Perhaps the easiest will be as a replacement for natural gas derived from fossil fuels. Natural gas, a mix of methane and ethane, is used for heating, cooking and generating electricity. Hydrogen can be burned in the same way and produces only water (no CO₂), but you need roughly three times as much to produce the same amount of energy.

Hydrogen can also be used in fuel cells, where chemical energy is turned directly into electrical energy, much like a battery. These cells can be used instead of combustion engines in vehicles or instead of petrol or diesel generators.

WHERE WILL THE HYDROGEN COME FROM?

The gas can come from two sources, known as 'green' and 'blue' hydrogen. "Green hydrogen is produced by splitting water into its constituent parts, hydrogen and oxygen, using electricity from renewable sources such as wind or solar power," says Dr Eike Thaysen, experimental geosciences technical research assistant at the University of Edinburgh. "Blue hydrogen is produced by the reaction of steam with methane."

Since green hydrogen is produced with renewable energy, it can be used as a way of storing surplus renewable energy. Blue hydrogen, however, is produced using fossil fuels, so creates carbon emissions, but the CO₂ is captured and stored permanently underground.

Although, in August, *The Guardian* reported that the carbon capture technology fails to store between 5 and 15 per cent of emissions, resulting in eight million tonnes of CO₂ emissions annually by 2050, based on the government's planned usage of blue hydrogen. Another study by scientists from Cornell

and Stanford Universities suggested that it could be even worse. They estimate that the emissions are equivalent to 139g of CO₂ per million joules of energy, with a carbon footprint 20 per cent greater than burning natural gas or coal.

SO WHY USE BLUE HYDROGEN AT ALL?

For one thing, the Cornell and Stanford study may not be applicable to the UK, according to Stuart Haszeldine, professor of carbon capture and storage at the University of Edinburgh. "[It] takes worst possible case assumptions based on a leaky USA system – that lots of methane will leak and very little CO₂ will be captured. So it's not surprising that you end up with a very large CO₂ emission per unit of hydrogen," he says. "Even so, I regard low-carbon blue hydrogen as a transition [fuel] – its replacement by cleaner green hydrogen will be determined by the pace at which the price of electrolysis drops."

Thaysen says a more accurate estimate of the emissions for blue hydrogen would be 10-20g of CO₂ for each million joules of energy produced. For the same amount of energy, burning natural gas produces about 63g of CO₂. "Blue hydrogen is about three to six times cleaner than natural gas, provided the carbon is split off and stored," she says. So even if 15 per cent of the CO₂ emissions escape, the total emissions are still much less.

Thaysen also believes that blue hydrogen is essential to reach net zero. "Green hydrogen ➤

LEFT 'Green' hydrogen, produced by renewable fuels, could be a step on the path to reaching net-zero emissions

BELOW Hydrogen fuel cell cars have the range of fossil fuel vehicles, but currently lack the refuelling network



• enables decarbonised storage of renewable energy, thereby fuelling increased use of zero-carbon energy sources and helping the transition to a net-zero society,” she says. “Blue hydrogen, however, is currently more economical and uses existing technologies, which helps develop value chains and can help industry cut emissions quickly. It also ensures there’s a market for green hydrogen once it becomes cost-competitive. A combination of green and blue hydrogen will be essential to get us to net zero fast.”

WHAT INFRASTRUCTURE IS NEEDED?

Converting the gas supply to our homes to hydrogen will be comparatively simple, thanks to the infrastructure that’s already in place. Hydrogen can be blended, at up to 20 per cent of the gas volume, into the existing gas network without changing the infrastructure or our appliances. “This makes the conversion to hydrogen rapid and low-cost. But it only results in a 7 per cent reduction on CO₂ emissions, so we want to be aiming for 100 per cent hydrogen,” Thaysen says. “But to convert to 100 per cent hydrogen, adaptations to the current infrastructure are needed. To get the gas from the distribution sites into our homes, we’re very fortunate because the yellow polyethylene pipes that are currently being installed across the country to replace the old iron pipes are suitable for hydrogen.”

For drivers, vehicles with a hydrogen fuel cell might seem like the perfect compromise between a fossil-fuel car and an electric vehicle. But the main issue for consumers is where to fill up. UK H2Mobility lists only 11 hydrogen fuel stations for cars nationally, mostly around London.

SO, IS HYDROGEN THE ANSWER TO REACHING NET ZERO?

“Hydrogen has the potential to be very useful. It could reach the aviation and industrial sectors that other options can’t,” says Robert Gross, professor of energy policy and technology at Imperial College. “But we won’t be able to use it everywhere at once. The sheer volume of energy needed for domestic heating and transport, is immense. Considering the minuscule amount of hydrogen we use for energy today, the challenge is huge. So hydrogen won’t be a quick fix or a universal panacea.”

by **SARA RIGBY**

Sara is the online assistant at BBC Science Focus. She has an MPhys in mathematical physics.



ANALYSIS

LONELINESS: IS IT INEVITABLE IN A MODERN WORLD?

Young or old, rich or poor, many of us will experience a longing for social contact at some point in our lives. But loneliness doesn't have to be inevitable

It may seem an obvious outcome of a pandemic where social contact is discouraged, even made illegal, but concerns about rising levels of loneliness were common before the coronavirus and will likely persist for the foreseeable future.

Humans are an incredibly social species. It's one of the reasons we have such powerful brains and advanced intelligence – to better keep track of and maintain



“Completely depriving someone of human contact is a recognised form of torture”

This is less and less common in the modern world. Blame capitalism, neoliberalism, individualism, globalisation, technology or anything else that undoubtedly had a part to play in bringing about such change. The fact is, spending your whole life in the same community and region is not the default now. Many of us go off to university, or relocate across the country, even across continents, chasing the available jobs and opportunities (just ask any academic). While this may be the best approach on an individual basis, it means we often lack the ability, or opportunity, to ‘put down roots’, and thus build up a network of friends and relations that could be relied upon to counteract loneliness. So, thanks to the world we’ve created for ourselves, is loneliness inevitable?

Not quite, because the mechanisms of loneliness aren’t as straightforward as we might think. The traditional image tied to the loneliness epidemic is that of an older person, past retirement age, living alone, because the modern world and the march of time has deprived them of the ability to interact with close friends and family. And while there are undoubtedly many examples of such people out there, recent evidence suggests that the actual picture is more complex.

For instance, a 2018 survey of 20,000 Americans found fewer elderly people experienced loneliness than younger generations, even though the older generations were less likely to be able to do anything about their loneliness. According to a recent study at Harvard University, older teens and young adults seem to be hit hardest by loneliness overall, particularly during the pandemic. This actually makes a certain amount of sense; elderly people have lived much longer and have thus had more time to cultivate lasting relationships, while younger people haven’t.

Also, feelings of loneliness are logically more likely in younger generations, given that their brains are extra-sensitive to peer approval and relationships. Plus, those in the younger generation find

numerous relationships. Our social interactions are a huge factor in how we think, act and see ourselves, because much of our brains are dedicated to social cognition. Completely depriving someone of human contact is a recognised form of torture.

Human wellbeing depends on interpersonal interactions and relationships. It’s no wonder that prolonged loneliness is associated with many serious health consequences, such as an increased risk of depression, anxiety, dementia, stroke and heart disease, so an epidemic of it should be taken very seriously.

Is it inevitable, though? Are humans destined to experience loneliness, no matter what we do? That may seem to be the case when you look at it from a certain angle. While we’re undeniably social, humans also evolved in a tribal setting, where a few dozen individuals stuck together for their entire (short) lives. This has undoubtedly shaped how we work and what we’ve become. In the grand scheme of things, until relatively recently, in the developed world at least, the average human lived an existence that didn’t much deviate from this. We typically lived, worked and raised families as part of tight communities, where everyone knew everyone else and there was always someone around.

ABOVE Concerns over levels of social isolation and its effects on people’s mental health were growing before the lockdowns of the COVID-19 pandemic



People who grew up with the internet have the skills to connect meaningfully online, but older individuals can find it a struggle

● themselves in an increasingly demanding and uncertain world where the traditional means of fostering relationships become ever more difficult. The main issue here is that younger people still have ample time and capacity to make friends and forge meaningful connections, while lonely elderly people seldom do.

Also, a recent study by the National Institute on Aging found that loneliness and social isolation seem to be different things. This means you can actually be cut off from much human contact and not necessarily feel lonely. On the flip side, you may have a lot of human contact, but still feel lonely. This is likely because loneliness comes from a lack of emotionally rewarding meaningful connections. As long as you have a few of those, you may still avoid feelings of loneliness.

It's not so much that loneliness is inevitable, so much as the world around us keeps changing and long-established means of maintaining relationships or a communal existence often no longer apply. People experiencing loneliness is a likely outcome of this. But while the world around is changing, so are the people in it. Recent studies show that lonely elderly people taught to use social media experience little to no change in their loneliness, while younger people, born and raised in an online world, readily form meaningful relationships online (for better or worse). Unless something drastic happens in the interim, it suggests that when the younger generations become the older generations, they'll not struggle with alleviating their loneliness via the internet.

All in all, it could be argued that increasing loneliness is one, admittedly common, consequence of a world and society constantly undergoing significant change. But increasing acceptance of things such as remote technological connections and movement away from habits like suppressing or denying emotions (particularly in men), could well counteract it.

It may be that loneliness is something experienced by many people for many years to come. But it need not be permanent and it need not be inevitable.

by **DR DEAN BURNETT**

Dean is a neuroscientist and the author of the bestselling books *The Idiot Brain* and *The Happy Brain*.

COMMENT

MORE ME, NOW: IS NARCISSISM ON THE RISE?

Are we becoming more narcissistic? And is social media behind the seemingly growing me crowd?

It's almost a cliché for people to talk about how we've all become narcissists, because social media has turned us into selfie-obsessed, image-crafters. This is particularly assumed to be the case for the 'me, me, me' generation: millennials. But, are we more narcissistic today, or is this just the age-old scepticism about 'kids these days' built on stereotypes and misplaced nostalgia?

First of all, what is narcissism and is it inherently bad? In May 2021, Ohio State University academics Sophie Kjærvik and Prof Brad Bushman published a review of 437 studies on narcissism, which together included 123,043 participants. In it, they defined narcissism as "entitled self-importance", explaining that "people with high levels of narcissism think they're special people who deserve special treatment. They have an exaggerated and inflated sense of their own importance."

In 2014, Bushman co-created a scale that was surprisingly good at identifying narcissists. It consisted exclusively of a response to the question: to what extent do you agree with this statement: I am a narcissist. It turns out that lots of narcissists know they're narcissists and some are even quite proud of it.

Since then Bushman has changed how he talks about narcissism. Something the researchers stress in the 2021 article is that they didn't call anyone a narcissist and instead said that people were either 'high' or 'low' on narcissism.

Does this mean that we should abandon the term narcissist? Perhaps, as they explain, "Calling someone a narcissist implies that narcissism is a dichotomous variable, which it's not." We're all somewhere on a scale and most of us have some narcissistic traits.

Also, there's more than one type of narcissism. More accurately, there's a core part of narcissism – entitlement – and at least two important dimensions. Both the public and academics have focused almost entirely on the dimension called grandiose narcissism. As Kjærvik and Bushman explain, "Individuals high in grandiose narcissism tend to have high levels of self-esteem... self-assuredness, imposingness, entitlement, exhibitionism, self-indulgence and disrespect for the needs of others".

The other, often overlooked, dimension is vulnerable narcissism, which is marked by low self-esteem,

“While some research has found that there can be benefits to narcissism (it can make people more likeable in the short term, for example) there’s also a darker side”

“hypersensitivity to evaluations from others, defensiveness, bitterness, anxiousness, self-indulgence, conceitedness, arrogance and an insistence on having one’s own way,” explain Kjærvik and Bushman.

Grandiose and vulnerable narcissism can appear similar but come from very different places. It’s the difference between posting a selfie because you think you look great and everyone needs to see (grandiose) and posting a selfie because you’re feeling down and are looking for some external validation (vulnerable). The behaviour is the same, but the reasons behind it are almost opposites. No single act should make you score high on narcissism, but the more behaviours like this you engage in, the more likely you are to be classified as such.

While some research has found that there can be benefits to narcissism (it can make people more likeable in the short term, for example) there’s also a darker side. Kjærvik and Bushman found that there was a significant relationship between narcissism and aggression, regardless of whether people were higher on the grandiose or vulnerable dimensions, and they argue that it’s a risk factor for violence.

This relationship might be more complicated however, and other research has found that only vulnerable narcissism seems to be linked with ‘narcissistic rage’ – an explosive mix of anger and hostility. If the me, me, me generation does exist, then this is bad news.

People certainly seem to think that we’re becoming more narcissistic. In research published in 2019, Joshua Grubbs and colleagues found that people of all ages, tend to view adolescents and “emerging adults” as the most narcissistic and self-entitled age groups. As you might expect, they also found that this perception was exaggerated as people got older. In other words, the greater the age gap between millennials and the person rating them, the harsher the assumptions of narcissism became (the ‘kids these days’ stereotype).

As for whether this perception is true, in 2008 Prof Jean Twenge and her team tried to find out by looking at generational change. They compared 85 samples of participants who completed the Narcissistic Personality Inventory scale between 1979 and 2006, and found that narcissism levels in US college students rose by 30 per cent over this period. If this



trend continues today, which many scholars seem to think it has, then the answer is yes, we are becoming more narcissistic.

The increase that Twenge and colleagues found was mostly before the advent of social media. So what caused the change? They argued that it was probably an increase in individualism within society.

If it’s true that so many more young people are scoring high on narcissism today, perhaps this is due to changes in our environments rather than changes in our minds. Yes, we post pictures of ourselves online and yes this can look narcissistic. But the reasons behind these posts are myriad. Can the current construct of narcissism capture this new reality?

As researcher Keith Campbell wrote in 2001 “narcissism may be a functional and healthy strategy for dealing with the modern world”. In which case, perhaps it’s time for us to rethink this seemingly abundant phenomenon. **SF**

by **DR JULIA SHAW**

Julia is a research associate at University College London and the co-host of the Bad People podcast on BBC Sounds. She is an expert on criminal psychology, and the author of Making Evil and The Memory Illusion.

ABOVE Selfies can be driven by both grandiose and vulnerable narcissism

Apple's new AirPods Max are much prettier than the standard AirPods, in our opinion p31



INNOVATIONS

PREPARE YOURSELF FOR TOMORROW



Three hurricanes brewing in the Atlantic region

HIGH-TECH DISASTER MITIGATION

**SEAFLOOR SCANNER**

Since 2018, a shallow water buoy developed at the University of South Florida has been floating in the Gulf of

Mexico monitoring the seafloor. It's scanning for tiny movements that indicate an earthquake or tsunami is imminent, which usually requires devices working at greater depths.

**GOOD VIBRATIONS**

'Vibration barriers' to protect old buildings in earthquake zones were proposed by engineers at

the University of Brighton in 2015. A box containing a mass suspended on springs would be sunk into the ground to absorb the seismic waves, reducing their strength.

**SNOW PATROL**

After a deadly avalanche in Svalbard in 2015, researchers from Norway have been installing instruments that

measure snowfall and snow pressure. The project is intended to investigate the differences between Arctic and alpine avalanches and improve the design of snow fences.

CLIMATE

Could we cool the oceans to snuff out storms?

Ever used a straw to blow bubbles in a drink? One company is scaling up that idea in the hopes of stopping hurricanes in their tracks

Of the many problems climate change poses, rising sea temperatures have the potential to be the most catastrophic. Warmer oceans mean rising sea levels, melting ice caps and more extreme weather events, including hurricanes. But a Norwegian company claims to have a way to mitigate that last one.

OceanTherm, founded by Olav Hollingsaeter, a former naval officer, is developing a system that uses bubbles to cool the sea's surface by drawing up cold water from the depths.

Hurricanes are created when hot and cold air meet over warm ocean waters of 26.5°C or above. The warmer the water, the more powerful a hurricane can become. But water below 26.5°C has neither the heat nor sufficient levels of evaporation to feed a hurricane, and so will reduce its strength.

OceanTherm's idea is to lower perforated pipes into the ocean through which to blow compressed air. The air creates bubbles to draw colder water up to the surface. The pipes would be deployed from a fleet of ships patrolling areas of likely hurricane formation – the Gulf of Mexico, for instance – and create a 'bubble curtain' in a hurricane's path to diminish it, or snuff it out altogether.

"THERE'S A HUGE DIFFERENCE BETWEEN KEEPING A FJORD FROM ICING OVER AND WEAKENING A TROPICAL CYCLONE"

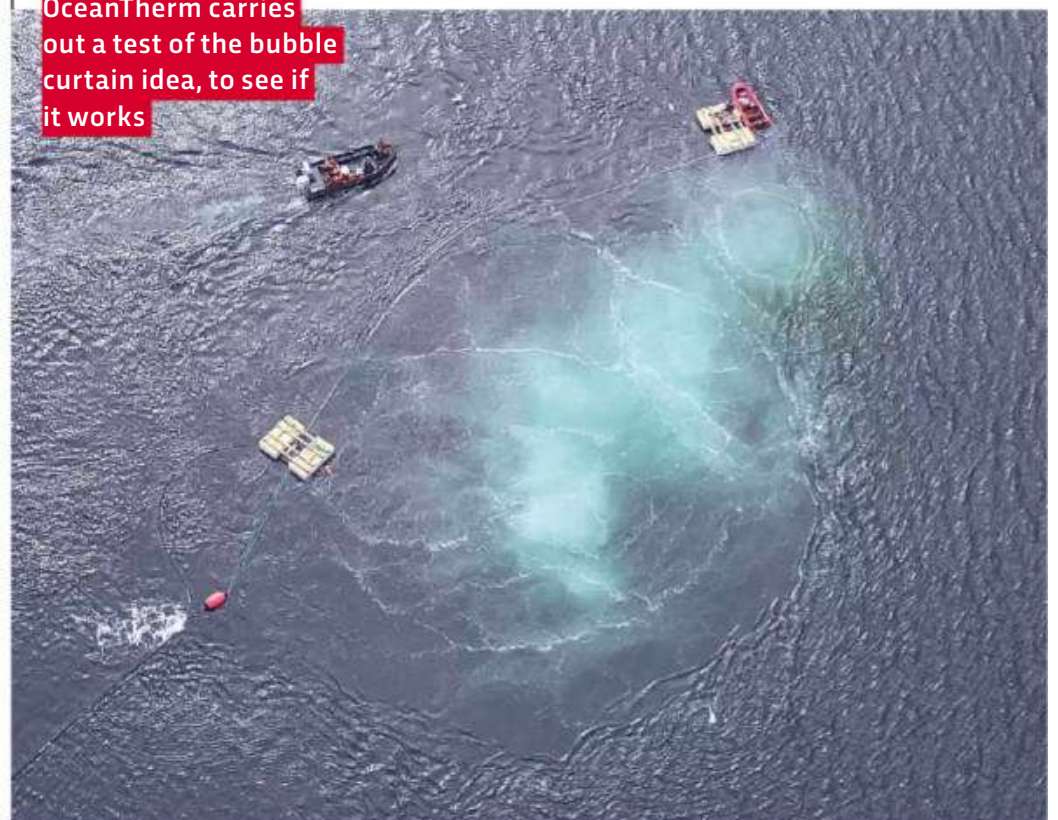
Norway has been using bubble curtains for years to prevent fjords from freezing in winter (in this case, the bubbles bring warmer water to a surface that's being chilled by cold air).

OceanTherm's proposal has yet to be tested on a hurricane and Hollingsaeter admits a lot of research and development is needed to make it viable, but experts are sceptical. "There's a huge difference between keeping a fjord from icing over and weakening a tropical cyclone with the power of several thousand nuclear bombs," says Bill McGuire, emeritus professor of earth sciences at University College London.

The practicalities of such a proposition (the number of ships required, getting them to the right place at the right time), not to mention the cost (estimated to be \$500m to set up, and over \$80m a year to run), would seem to be prohibitive. Although, perhaps less so when weighed against the expected costs of hurricane damage (\$54bn annually, according to the US Government's Congressional Budget Office).

There are cheaper alternatives, however. "The way to mitigate the effects of a landfalling hurricane is via better forecasting, improved land-use planning, more resilient construction, and improved alert and evacuation systems. And slashing emissions so that an overheating climate and ocean don't drive more powerful and wetter storms," says McGuire.

➤ **OceanTherm carries out a test of the bubble curtain idea, to see if it works**



ON TEST

APPLE AIRPODS MAX

Do these headphones justify the price tag?

There's a new kind of sound in town: spatial audio. **Daniel Bennett** tests Apple's new headphones alongside the latest development in surround sound to find out what the fuss is all about...

Let's cut to the chase: can a pair of wireless headphones really be worth £549? Ultimately that's the question facing anyone considering a pair of Apple's AirPods Max. The answer isn't one I expected to give, but yes, these headphones do justify their price tag.

It's not an insignificant amount of cash: £549 is PlayStation 5 money; it's package holiday abroad money. However, after a month's use, working mostly from home, the AirPods Max have barely left my head, such is the comfort, audio prowess and ease of use of Apple's new headphones. They're so good that I've exhausted my music library, sought out new albums and even started watching films on my iPad. The only caveat is that if you're not already invested in Apple's expensive ecosystem, many of the AirPods Max's best features will be lost to you.

DESIGN

The headphones are a world apart from the build of most wireless headphones,

which feel creaky and toy-like in comparison to Apple's familiar machined aluminium finish. The mesh textile on the headband and ear cups, as well as the memory foam inside, distribute the pressure across the surface of your head and face such a way that you can wear the headphones for hours on end without discomfort, even with glasses on. The mesh is also more breathable than the leather you traditionally find on headphones.

The build quality is as solid as you'd expect, it's only the price tag that stops me from chucking them in the bottom of my backpack. The ear cushions, which look like they might weather with age, snap on and off magnetically so it's easy (but expensive) to swap them out (new ear cushions are £75).

AUDIO QUALITY

An Apple H1 chip – a specialised audio processor chip built from the ground up by Apple – powers each earcup separately. While delivering sound to each ear, each chip

"ULTIMATELY, NEW HEADPHONES BOIL DOWN TO HOW THEY MAKE YOU FEEL ABOUT YOUR FAVOURITE ALBUMS WHEN YOU LISTEN TO THEM FOR THE 100TH TIME"

listens in to what's going on inside the earcup via eight microphones dotted in and around the headphones. They're looking for any distortion or interference caused by real-world use – maybe you're wearing glasses, maybe you're lying down – the idea is that they can make 200 adjustments per second to make sure the audio is consistently clear.

The outward effect of this unique tech puts these headphones in a class of their own. Like the very best hi-fi, these Apple headphones feel as though they completely open up your music. Listen to something like the noisy soundscapes of jazz rock band



WHAT'S GOOD?

- UNRIVALLED AUDIO QUALITY
- CLASS-LEADING NOISE-CANCELLING
- CINEMATIC SURROUND SOUND
- EXCEPTIONALLY COMFORTABLE FOR LONG PERIODS
- BEST IN CLASS BLUETOOTH CONNECTIVITY

WHAT'S BAD?

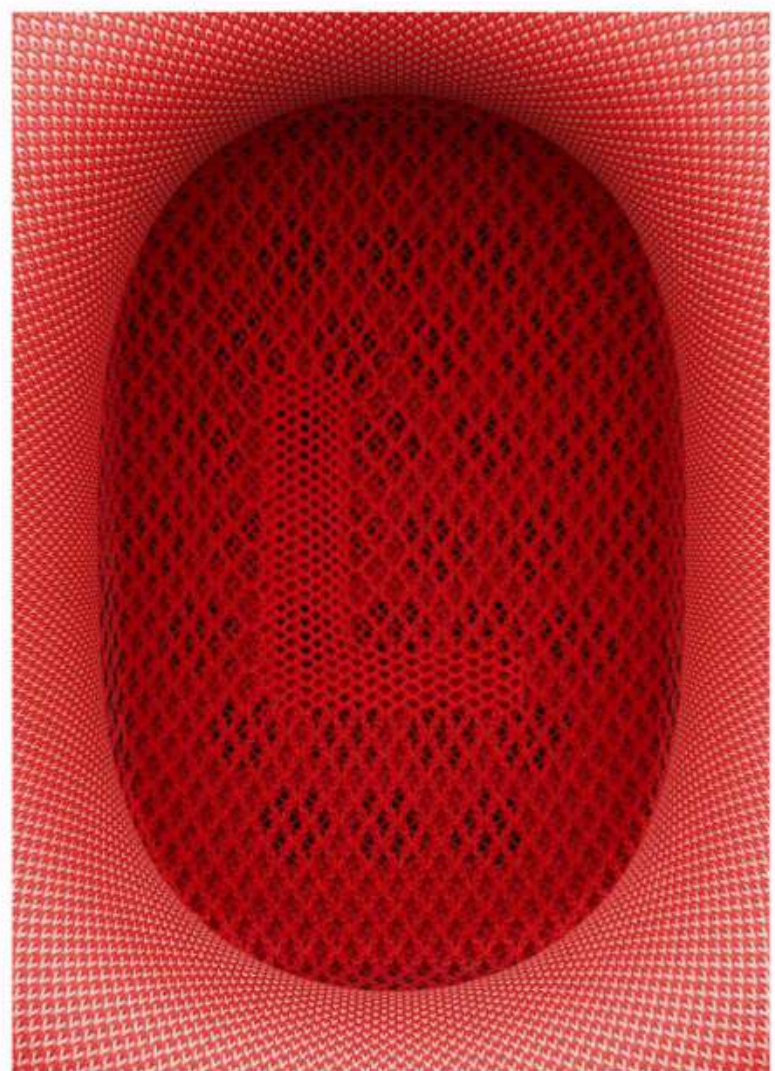
- STRANGE CASE
- AT ITS BEST IN THE APPLE ECOSYSTEM
- NO AUDIO CABLE INCLUDED

The Comet is Coming, and the huge bass and driving saxophone no longer drown out the detail of the synth and percussion playing in the mid-range. Switch to something more aggressive like Turnstile's latest hard rock album *Glow On* and the thrashing guitars feel like they have more crunch, the hi-hats more sparkle. It's all just a step closer to listening to your favourite band in the flesh than most wireless headphones can offer.

The headphones come into their own when paired with a source that has spatial audio. Apple's slowly adding this tech – powered in part by Dolby Atmos – to its music library. It's essentially an attempt to simulate your music coming from a 3D space, in other words

it mimics how music reaches your ears when you watch a live performance. Listen to *Blinding Lights* by The Weeknd and the 80s kick-and-snare drum intro sounds as though it's coming to you from the back of the room before the vocals hit front and centre. Freddie Mercury sounds like he's getting closer and closer as he builds into the verse of *Another One Bites The Dust*.

Spatial audio is even better with a movie. It simulates cinema surround sound in a way we've never heard on headphones before. Rubble and debris feel like they're flying around your head in the final scenes of *Avengers: Endgame* and Hans Zimmer's surging score for *Interstellar* really feels like it's enveloping you. An iPad and a pair of AirPods Max is



With memory foam and a mesh cover, the ear cushions are comfy for all-day wear and less sweaty than leather

Plenty of tech is stuffed inside the headphones to give you crisp and immersive spatial audio

as close as you're going to get to a mobile cinema.

There is one last trick these headphones pull off. Accelerometers inside track the position of your head relative to the device you're watching on – so if you turn your head to the left, the sound moves with it. It's uncanny the first time you realise what happening. Again, the idea is to more closely simulate audio in a real, live space.

VERDICT

While I wouldn't tell anyone to go and spend £549 on a pair of headphones, I would say that this is a purchase you won't regret. The Apple AirPods Max are a tier above any other wireless headphones, in almost every department: features, design and audio quality. They're just so functional and comfortable that you'll end up wearing them all the time. Ultimately, new headphones boil down to how they make you feel about your favourite albums when you listen to them for the 100th time, and the AirPods Max put a smile on my face every single time.



Ideas we like...

↓...a toilet that's flush with tech

Frankly, compared to East Asia, we're a bunch of Luddites when it comes to toilet tech in the West and it's about time that changed. Just look at what we could have! This collaboration between Duravit and Philippe Starck is the height of hygiene. Hidden within the toilet's ceramic shell is a seat heater, an odour extraction fan and a warm air dryer, alongside a suite of bidet functions that would put the Bellagio Fountains to shame. There's even a nightlight underneath so you don't have to turn the big light on during a nighttime visit.

Duravit & Philippe Starck
£TBC, duravit.us



↑...hi-fi PC speakers

Q Acoustics have shrunk their hi-fi expertise into these versatile stereo, wireless speakers that will connect to pretty much any device in the house. There's HD Bluetooth for streaming high-resolution audio wirelessly and a range of ports for wiring into laptops, TVs and turntables. Really, they're built to give your PC an audio leg-up, but they could tuck neatly into a bookshelf or sit either side of your TV. The speaker cabinets are built with the kind of bracing you'd find in high-end hi-fi setups, to keep the audio crystal clear, plus there's a socket to add a subwoofer if you want to add a little more bass.

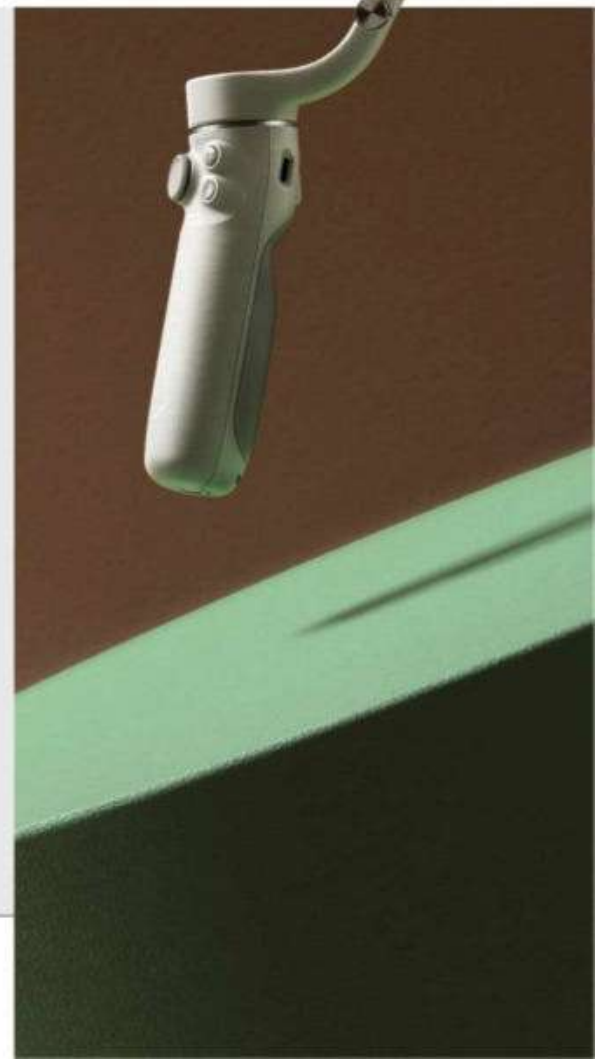
Q Acoustics M20
£399, qacoustics.co.uk



→...an amateur movie maker's best friend

A smartphone camera can do just about everything, except image stabilisation. Sure, some smartphones come with software that prevents blurry photos and smooths out video, but if you try to record a video while you walk down the street, the result is juddery, clunky footage that's hard to watch. This handheld, three-axis gimbal, powered by three motors and a clever algorithm, reacts to your every movement, cancelling it out to produce ultra-steady and cinematic video, even if it is your kid's first bike ride. DJI's Mimo app connects the smartphone and gimbal to each other, and from there you can control everything via handle's joystick. Alternatively the app can lock on to a face, an object or a dog to track it, keep it centre screen, in focus and steady, while you move around.

DJI OM6
£139, dji.com





←...electric commuter bikes

As cities look to clean their air and countries hope to curb their emissions, it's clear the great electrification is upon us. But it's not just cars that need to switch to battery power. As we all reconsider where we work and live, there are all kinds of opportunities for new vehicles like this cross-breed that's half-scooter, half-motorbike and all-electric. It's only a concept for now (boo!) but the bike would top out at 90km/h (56mph), and go 90km (56 miles) between charges, and look phenomenal while doing so.

BMW Motorrad Concept CE 02

£TBC, bmwgroup.com

↓...a replacement for pen and paper

This single-minded e-ink tablet has one purpose in life: to replace your notepad. The display will be familiar to anyone who's used an e-reader before, only this tablet comes with a stylus attached to the side that lets you write on the screen. The touchscreen will even mimic the sense and sound of running a pen across a page. Smart templates allow you to change the display to suit your needs: there are grids for graphs, calendars, to-do lists and dozens more. You can copy and paste, resize or edit your notes too – no more wishing you'd started that doodle a little further away from the margin. Once you're finished you can convert your handwriting into text (so long as it's legible), or save your notes to the cloud where you can access them from your computer or smartphone. You can scribble on PDFs or e-books too, or just use it as a standard reader. There are plenty more features, but we love how single-minded this device is, even if the price is a little steep for your next notebook.

reMarkable 2

£399, remarkable.com



↑...an affordable, top-of-the-range smartphone

These days it's almost a given that any 'flagship' mobile phone is going to cost upwards of £1,000, but here's a phone that challenges that. For £599, the 'mid-range' Xiaomi 11T Pro offers up a 6.7 AMOLED screen (one of the best mobile displays going), powered by two chipsets and paired with a 108-megapixel camera array. Plus, while the likes of Samsung and Apple have done away with in-the-box chargers, the 11T comes with a 120W plug device that the company says deliver a full charge in just 17 minutes.

Xiaomi 11T Pro

£599, xiaomi.com

Science Focus MAGAZINE

SUBSCRIPTION ORDER FORM

Please complete the order form and send to:
FREEPOST IMMEDIATE MEDIA (please write in capitals)

UK DIRECT DEBIT

☐ Yes, I would like to subscribe to/renew *BBC Science Focus* paying £22.99 every 7 issues – saving 40% *

YOUR DETAILS (ESSENTIAL)**

Title _____ Forename _____
Surname _____
Address _____

Postcode _____

Home phone no _____

Mobile phone no** _____

Email** _____

☐ I wish to purchase a gift subscription

GIFT RECIPIENT'S DETAILS (ESSENTIAL)**

Title _____ Forename _____ Surname _____

Address _____

Postcode _____ Home phone no _____

Mobile phone no** _____

Email** _____

Instructions to your bank or building society to pay by Direct Debit



To: the Manager (bank/building society)

Address _____

Postcode _____

Name(s) of account holder(s) _____

Bank/building society account number _____

Branch sort code _____

Reference number (internal use only) _____

Originator's identification number

7 1 0 6 4 4

Please pay Immediate Media Co Bristol Ltd debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with Immediate Media Co Bristol Ltd and, if so, details will be passed electronically to my bank/building society.

Signature _____

Date / /

Banks and building societies may not accept Direct Debit mandates from some types of account

KEEP IN TOUCH

BBC Science Focus Magazine (published by Immediate Media Company Limited) would like to send you updates, special offers and promotions by email. You can unsubscribe at any time. **Please tick here if you would like to receive these ☐

We would also like to keep in touch by post and telephone about other relevant offers and promotions from Immediate Media. For more information about how to change the way we contact you, and how we hold your personal information, please see our privacy policy, which can be viewed online at

www.immediate.co.uk/privacy-policy

OTHER PAYMENT METHODS

☐ **UK cheque/credit/debit card** – £57.75 for 14 issues, **saving 25%**

☐ **Europe inc Eire** – £92.54 for 14 issues

☐ **Rest of world** – £102.90 for 14 issues

☐ I enclose a cheque made payable to Immediate Media Co Ltd for £ _____

Visa ☐ Mastercard ☐ Maestro ☐

□□□□ □□□□ □□□□ □□□□

Issue no □□ Valid from □□□□ Expiry date □□□□

Signature _____ Date _____

If credit card address is different, please use the order hotline 03330 162 113

OVERSEAS Please complete the order form and send to: *BBC Science Focus Magazine*, PO Box 3320, 3 Queensbridge, Northampton, NN4 7BF

***Offer ends 3 November 2021.** Offer only available to UK residents paying by Direct Debit. 40% saving is only available to UK residents paying by Direct Debit. Your subscription will start with the next available issue.

You may photocopy this form

EASY WAYS TO ORDER

ONLINE
buysubscriptions.com/
SFP369

PHONE
03330 162 113[†]
(please quote SFP369)

POST
FREEPOST
IMMEDIATE MEDIA
(please write in capitals)

[†] UK calls will cost the same as other standard fixed-line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages, call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 9am-5pm. If calling from overseas, please call +44 1604 973 721.



INTRODUCTORY SUBSCRIPTION OFFER!

SAVE

40%

WHEN YOU SUBSCRIBE TO *BBC SCIENCE FOCUS* TODAY*

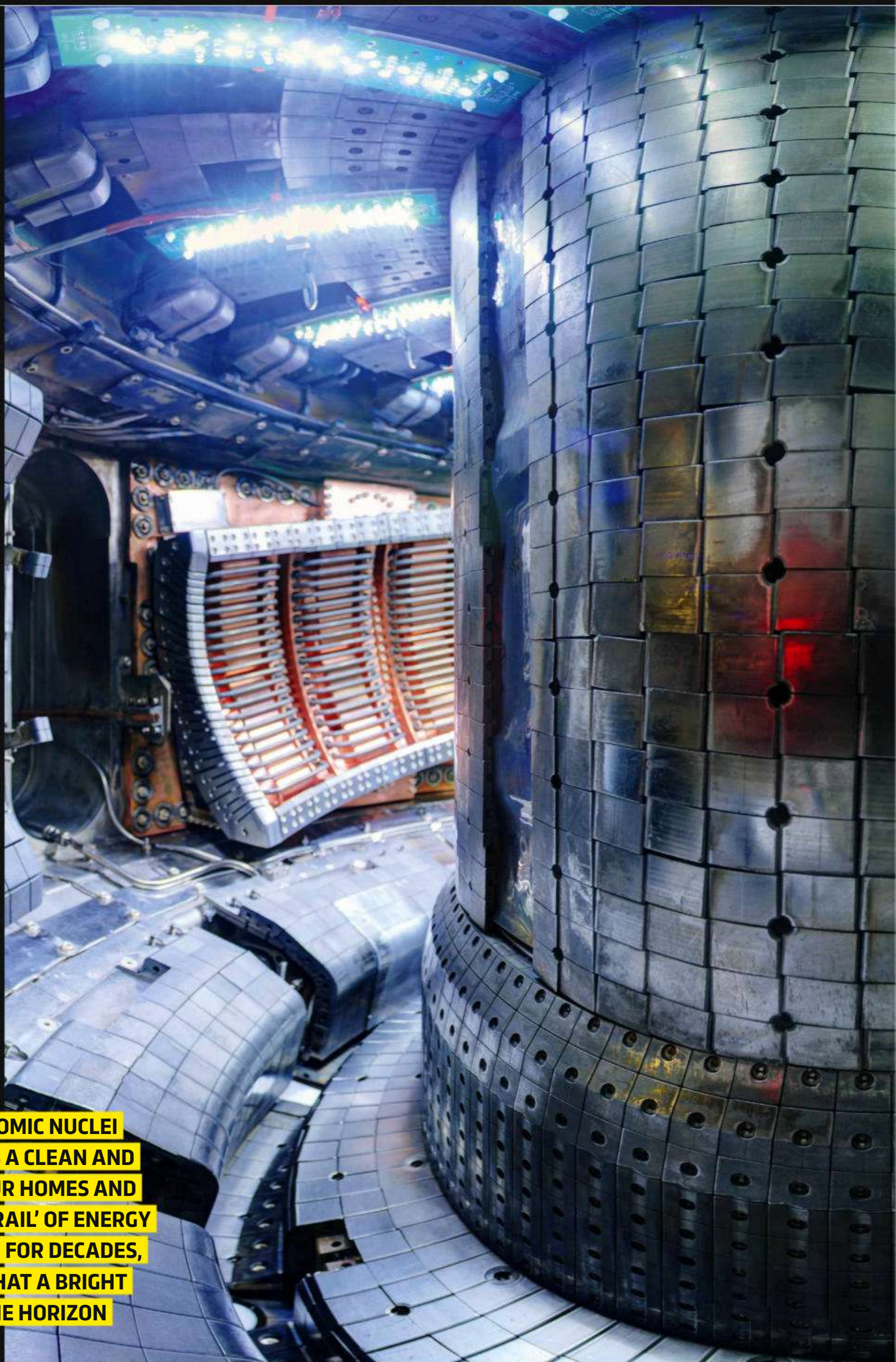
- **Save 40%** on the shop price
- Pay **just £22.99 every 7 issues** by Direct Debit, saving 40%!*
- Receive every issue delivered direct to your door with **FREE UK delivery**



FUSION'S TIME TO SHINE

FUSION – COMBINING ATOMIC NUCLEI TO RELEASE ENERGY – IS A CLEAN AND SAFE WAY TO POWER OUR HOMES AND INDUSTRY. THIS ‘HOLY GRAIL’ OF ENERGY HAS ELUDED PHYSICISTS FOR DECADES, BUT THERE ARE SIGNS THAT A BRIGHT FUTURE COULD BE ON THE HORIZON

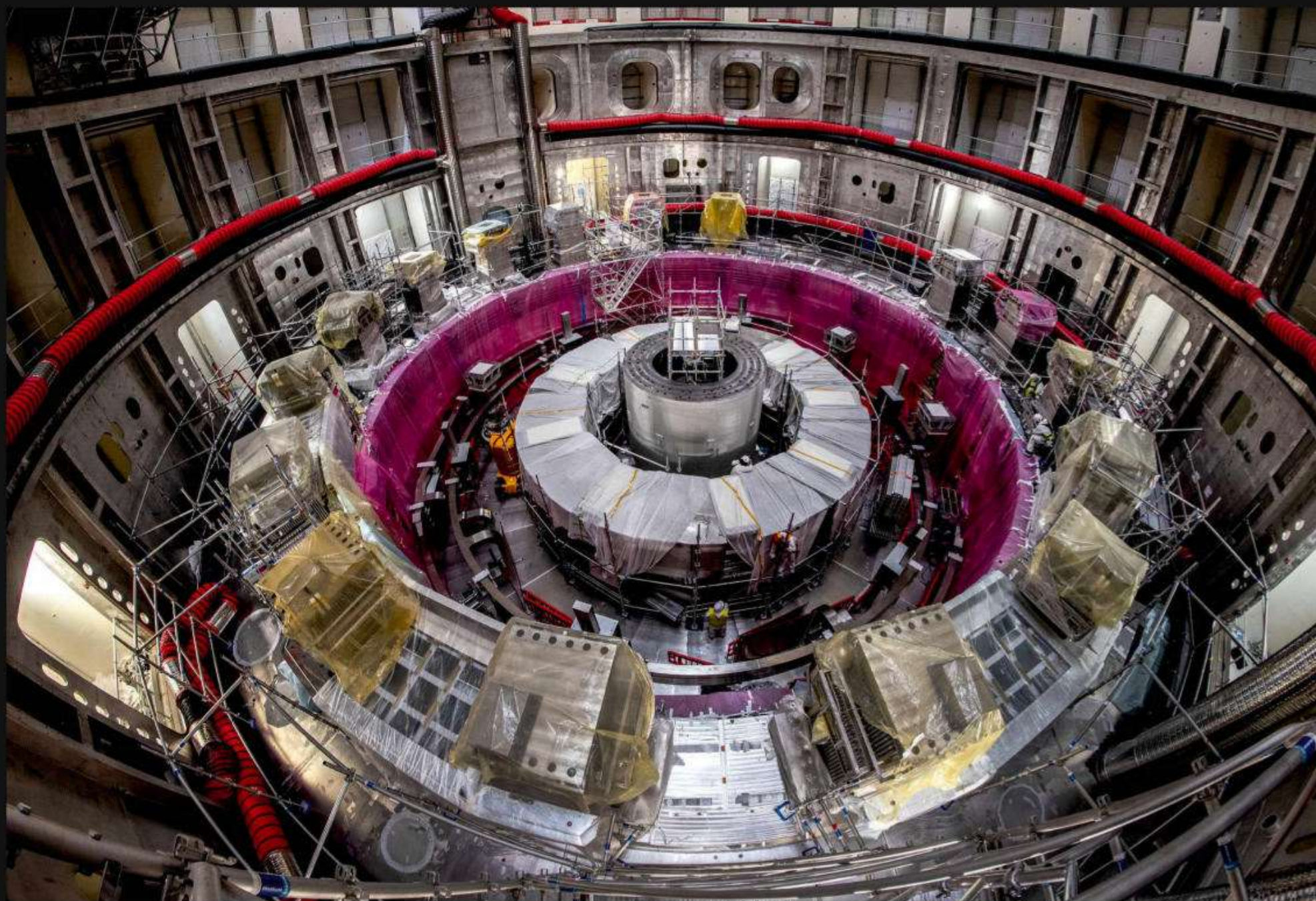
WORDS: ANDY RIDGWAY





Inside the doughnut-shaped vacuum chamber of the Alcator C-mod reactor at MIT Plasma Science and Fusion Center

BOB MUMGARD/CREATIVE COMMONS



It sounds like the stuff of dreams: a virtually limitless source of energy that doesn't produce greenhouse gases or radioactive waste. That's the promise of nuclear fusion, which for decades has been nothing more than a fantasy due to insurmountable technical challenges. But things are heating up in what has turned into a race to create what amounts to an artificial sun here on Earth, one that can provide power for our kettles, cars and light bulbs.

Today's nuclear power plants create electricity through nuclear fission, in which atoms are split. Nuclear fusion however, involves combining atomic nuclei to release energy. It's the same reaction that's taking place at the Sun's core. But overcoming the natural repulsion between atomic nuclei and maintaining the right conditions for fusion to occur isn't straightforward. And doing so in a way that produces more energy than the reaction consumes has been beyond the grasp of the finest minds in physics for decades.

But perhaps not for much longer. Some major technical challenges have been overcome in

the past few years and governments around the world have been pouring money into fusion power research. There are also over 20 private ventures in the UK, US, Europe, China and Australia vying to be the first to make fusion energy production a reality.

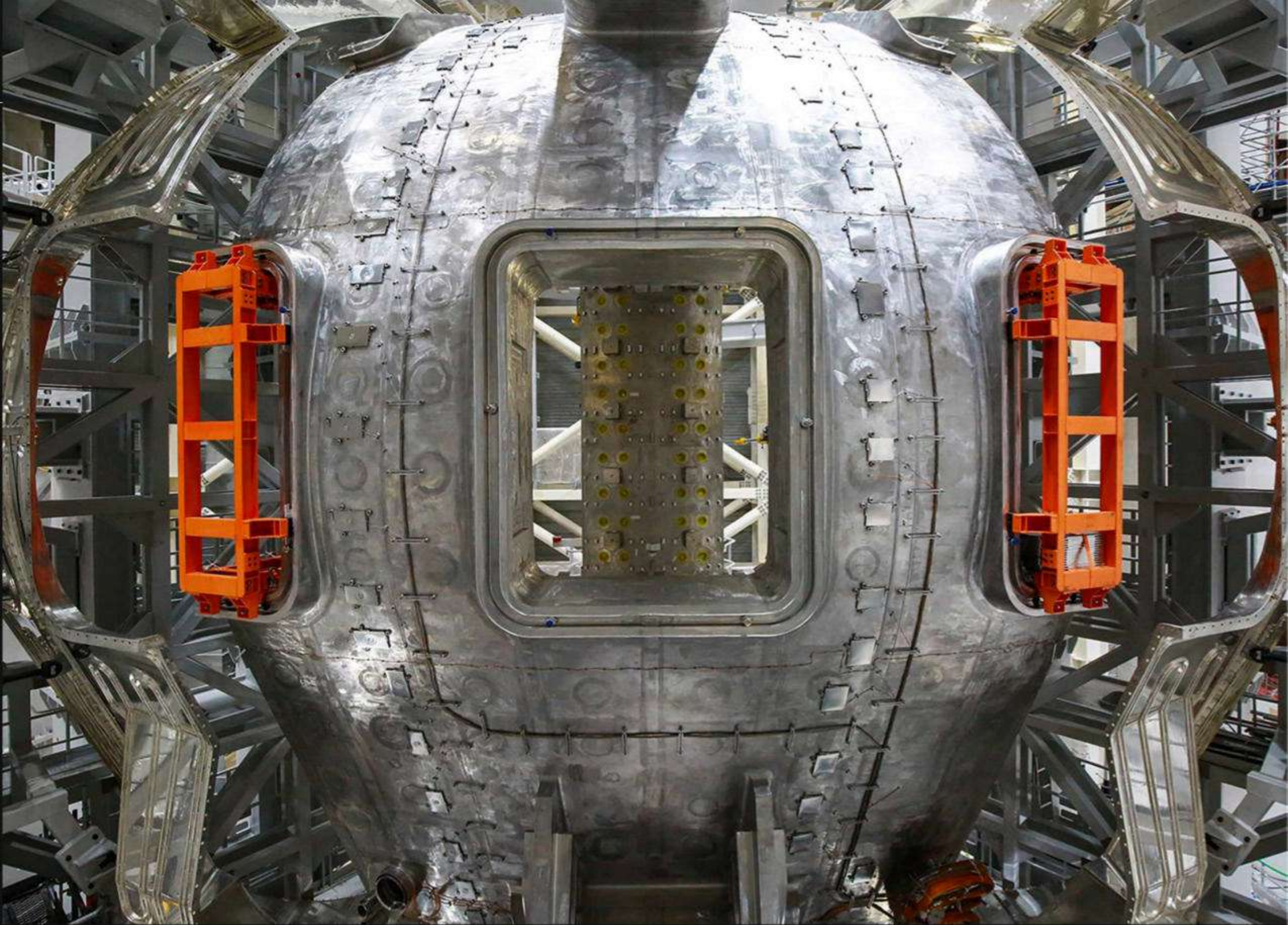
"People are saying, 'If it really is the ultimate solution, let's find out whether it works or not,'" says Dr Tim Luce, head of science and operation at the International Thermonuclear Experimental Reactor (ITER), being built in southeast France. ITER is the biggest throw of the fusion dice yet. Its \$22bn (£15.9bn) build cost is being met by the governments of two-thirds of the world's population, including the EU, the US, China and Russia, and when it's fired up in 2025 it'll be world's largest fusion reactor. If it works, ITER will transform fusion

"PEOPLE ARE SAYING, 'IF IT REALLY IS THE ULTIMATE SOLUTION, LET'S FIND OUT WHETHER IT WORKS OR NOT'"

ABOVE 35 nations have invested in the ITER, which is being built in France

ABOVE RIGHT The doughnut-shaped chamber at the heart of ITER

RIGHT China's EAST reactor managed to maintain plasma at 120,000,000°C for 101 seconds in June



power from being the stuff of dreams into a viable energy source.

HEAT AND PRESSURE

ITER will be a tokamak reactor – thought to be the best hope for fusion power. Inside a tokamak, a gas, often a hydrogen isotope called deuterium, is subjected to intense heat and pressure, forcing electrons out of the atoms. This creates a plasma – a superheated, ionised gas – that has to be contained by intense magnetic fields. The containment is vital, as no material on Earth could withstand the intense heat (100,000,000°C and above) that the plasma has to reach so that fusion can begin. It's close to 10 times the heat at the Sun's core, and temperatures like that are needed in a tokamak because the gravitational pressure within the Sun can't be recreated.

When atomic nuclei do start to fuse, vast amounts of energy are released. While the experimental reactors currently in operation release that energy as heat, in a fusion reactor power plant, the heat would be used to produce steam that would drive turbines to generate electricity. ►





**“THIS JUNE, CHINA’S
EXPERIMENTAL
ADVANCED
SUPERCONDUCTING
TOKAMAK REACTOR
MAINTAINED A PLASMA
FOR 101 SECONDS
AT 120,000,000 °C”**

LEFT The team at China’s EAST reactor inspect and adjust the device ahead of its record-breaking demonstration in June

► Tokamaks aren’t the only fusion reactors being tried. Another type of reactor uses lasers to heat and compress a hydrogen fuel to initiate fusion. This August, one such device at the National Ignition Facility, at the Lawrence Livermore National Laboratory in California, generated 1.35 megajoules of energy. This record-breaking figure brings fusion power a step closer to net energy gain, but most hopes are still pinned on tokamak reactors rather than lasers.

In June, China’s Experimental Advanced Superconducting Tokamak (EAST) reactor maintained a plasma for 101 seconds at 120,000,000°C. Before that, the record was 20 seconds. Ultimately, a fusion reactor would need to sustain the plasma indefinitely – or at least for eight-hour ‘pulses’ during periods of peak electricity demand.

A real game-changer for tokamaks has been the magnets used to produce the magnetic field. “We know how to make magnets that generate a very high magnetic field from copper or other kinds of metal, but you would pay a fortune for the electricity. It wouldn’t be a net energy gain from the plant,” says Luce.

The solution is to use high-temperature, superconducting magnets made from superconducting wire, or ‘tape’, that has no electrical resistance. These magnets can create intense magnetic fields and don’t lose energy as heat. “High temperature superconductivity has been known about for 35 years. But the manufacturing capability to make tape in the lengths that would be required to make a reasonable fusion coil has just recently been developed,” says Luce. One of ITER’s magnets, the central solenoid, will produce a field of 13 tesla – 280,000 times Earth’s magnetic field.

The inner walls of ITER’s vacuum vessel, where the fusion will occur, will be lined with beryllium, a metal that won’t contaminate ►

SHUTTERSTOCK

the plasma much if they touch. At the bottom is the divertor that will keep the temperature inside the reactor under control. “The heat load on the divertor can be as large as in a rocket nozzle,” says Luce. “Rocket nozzles work because you can get into orbit within minutes and in space it’s really cold.” In a fusion reactor, a divertor would need to withstand this heat indefinitely and at ITER they’ll be testing one made out of tungsten.

Meanwhile, in the US, the National Spherical Torus Experiment – Upgrade (NSTX-U) fusion reactor will be fired up in the autumn of 2022. One of its priorities will be to see whether lining the reactor with lithium helps to keep the plasma stable.

MORE POWER

Instead of just using deuterium as the fusion fuel, ITER will use deuterium mixed with

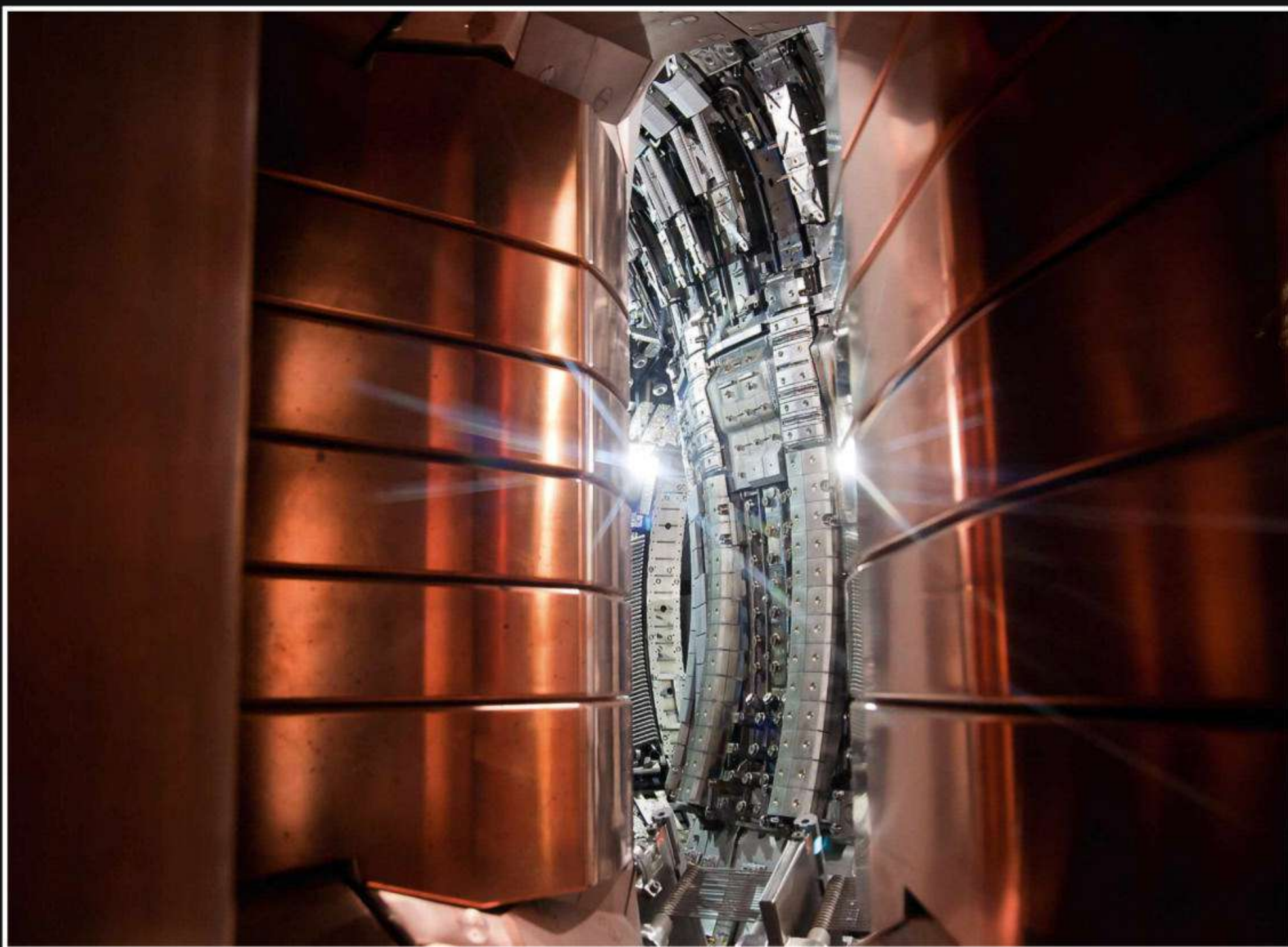
tritium, another hydrogen isotope. The deuterium-tritium blend offers the best chance of getting significantly more power out than is put in. Proponents of fusion power say one reason the technology is safe is that the fuel needs to be constantly fed into the reactor to keep fusion happening, making a runaway reaction impossible.

Deuterium can be extracted from seawater, so there’s a virtually limitless supply of it. But only 20kg of tritium are thought to exist worldwide, so fusion power plants will have to produce it (ITER will develop technology to ‘breed’ tritium). While some radioactive waste will be produced in a fusion plant, it’ll have a lifetime of around 100 years, rather than the thousands of years from fission.

As *BBC Science Focus* went to press in September, researchers at the Joint European Torus (JET) fusion reactor in Oxfordshire were

BELOW The Joint European Torus (JET) reactor in the UK is working on deuterium-tritium fusion reactions intended to sustain higher power outputs for longer

BELOW RIGHT The NSTX-U reactor has been designed to create a spherical plasma, in contrast to the toroidal (doughnut-shaped) plasmas of other tokamaks



EUROFUSION CONSORTIUM, ELLE STARKMAN/PRINCETON PLASMA PHYSICS LABORATORY

“ITER WILL PRODUCE ‘FIRST PLASMA’ IN DECEMBER 2025 AND BE CRANKED UP TO FULL POWER OVER THE FOLLOWING DECADE”

include finding the best combination of deuterium and tritium, and establishing how the current is increased in the magnets before fusion starts.

The groundwork laid down at JET should accelerate ITER's efforts to accomplish net energy gain. ITER will produce ‘first plasma’

due to start their deuterium-tritium fusion reactions. “JET will help ITER prepare a choice of machine parameters to optimise the fusion power,” says Dr Joelle Mailloux, one of the scientific programme leaders at JET. These parameters will

in December 2025 and be cranked up to full power over the following decade. Its plasma temperature will reach 150,000,000°C and its target is to produce 500 megawatts of fusion power for every 50 megawatts of input heating power.

“If ITER is successful, it’ll eliminate most, if not all, doubts about the science and liberate money for technology development,” says Luce. That technology development will be demonstration fusion power plants that actually produce electricity. “ITER is opening the door and saying, yeah, this works – the science is there.” **SF**

by **ANDY RIDGWAY**

Andy is a journalist based in Bristol and senior lecturer in science communication at UWE Bristol.





THE SCIENCE OF

DUNE

THE IDEAS, SCIENCE AND HISTORY DRIVING THIS
DECADE'S BIGGEST SCI-FI FILM

WORDS PAUL PARSONS

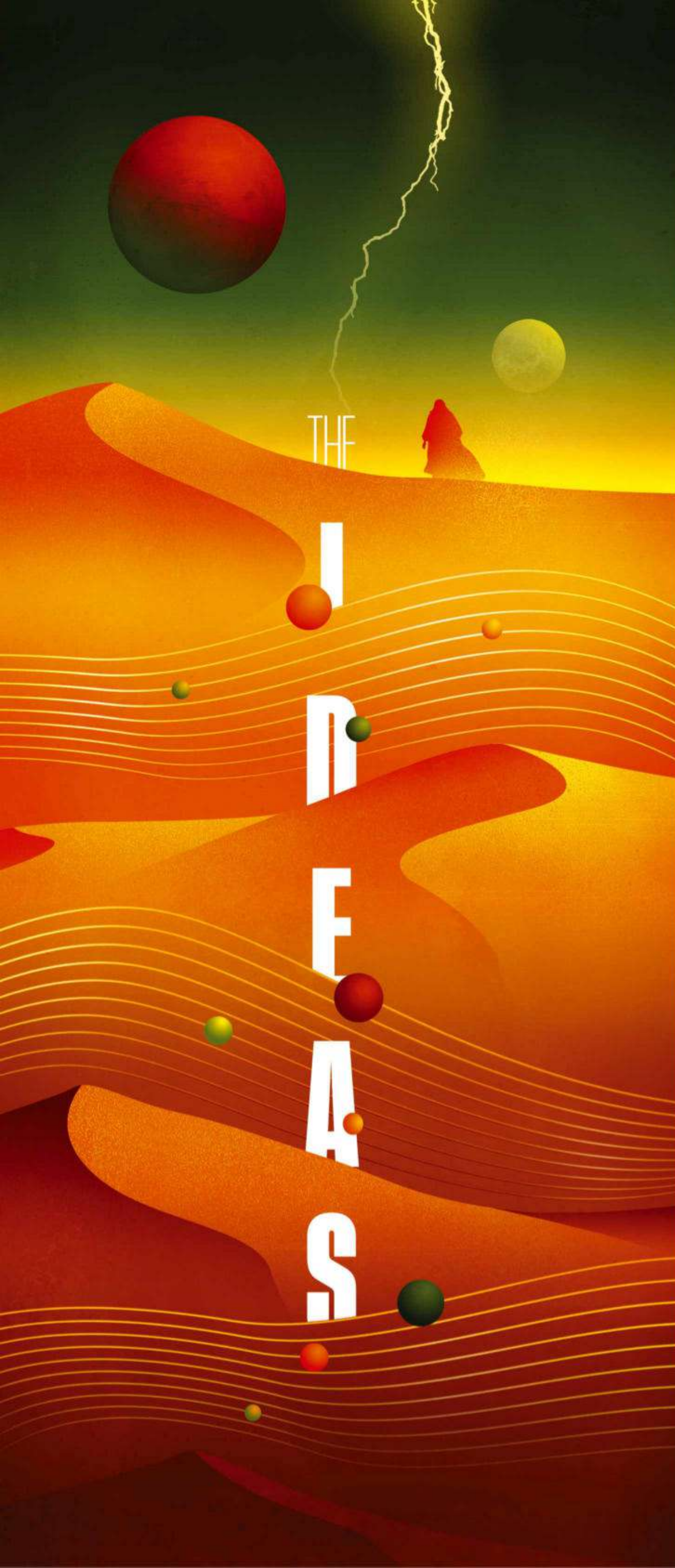
Arid deserts, alien worlds, mystical powers and galactic conflicts – all phrases that might call to mind images from the *Star Wars* universe. And yet they're at the root of an older, equally epic sci-fi saga that began more than a decade earlier, in 1965, when writer Frank Herbert published his debut novel *Dune*.

Set in the far future, when a human empire rules the Universe, *Dune* tells the story of a desert world wracked by conflict – and of the rise of an unlikely saviour.

On 22 October this year, director Denis Villeneuve, who directed two of the last decade's best science fiction films *Arrival* and *Blade Runner 2049*, is set to bring his own bold adaptation of *Dune* to UK cinema screens.

Get ready for space opera, superhumans, and more visual effects than you can shake a sandtrout at.

Oh, and maybe some science too.



THE ORIGIN STORY

***Dune* is a landmark in science fiction. It mixes stories about political greed, ecological abuse and unchecked technological progress in a fully realised universe. Award-winning science fiction author Stephen Baxter tells us where Frank Herbert's idea came from and how it shaped what came after it...**

WHERE DOES THE NOVEL *DUNE* SIT AS A MOMENT IN SCIENCE FICTION?

It's of its time. But it also transcends that time, in a way. I think in the 1960s it was one of what they used to call 'campus novels' because every trippy student used to read them. *Dune*, *Lord Of The Rings*, *Stranger In A Strange Land*... all immersive worlds, often with messianic heroes and expanded consciousness. That will be its pin in time. But also, I think it built on a lot of what had been going on in science fiction earlier, and it anticipated what came later.

WHAT WERE FRANK HERBERT'S INFLUENCES?

Herbert was born in 1920, and the *Dune* saga began with serials published in sci-fi magazines, in around 1963. So he was already 43 years old and he'd clearly grown up on a diet of the magazines and pulp literature that preceded what you might call modern sci-fi. And among the tropes that he picked up was the idea of galactic empires. At one end you've got Isaac Asimov and his *Foundation* series, but there were a couple of more fantastical galactic empire sagas too, such as EE 'Doc' Smith's *Lensman* saga.

There had also been some world-building exercises before *Dune*, trying to go beyond the kind of cartoonish world-building of previous generations. Hal Clement's *Close To Critical* in 1964 is one example, about a planet with very heavy gravity.

DID HE TAKE ANY INSPIRATION FROM SCIENCE?

At the time *Dune* was being developed, you also had the first space probes to the nearby planets. Today, we're used to the visions of Mars and Venus we have now, but I think at the time it was quite shocking to find that Mars was an arid desert, and Venus was this hellhole. Previous generations had extrapolated from Earth, so Venus was a hot, wet Earth and Mars a cold, dry Earth – but now they seemed completely different. Also the famous environmental book *Silent Spring* by Rachel Carson was published in 1962, and I think that was a big eye-opener.

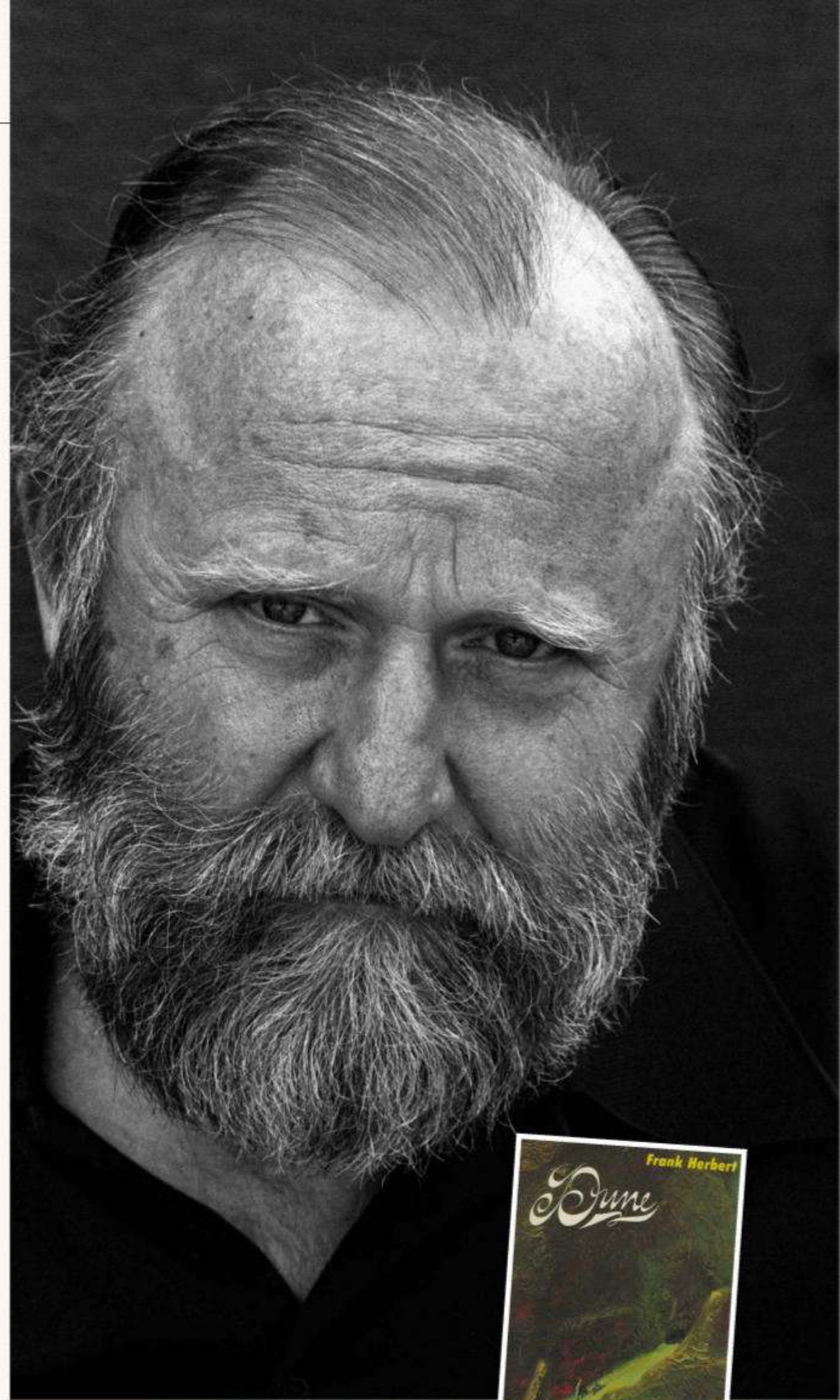
But there's a specific incident in Herbert's life that seems to have set him off in this direction. He made his living as a reporter before his fiction writing took off. In 1957, when he was in his 30s, he was sent to write about a system of dunes in Oregon that were migrating and therefore endangering towns. The US Department of Agriculture were using grasses to try and stabilise the dunes. And Herbert had been really struck by this – modifying an ecology to achieve a goal, as opposed to using technology, such as big fences. He became fascinated by deserts, and developed theories about how major religions often emerged from the deserts, which I guess is true – Islam, for instance. And it's thought that TE Lawrence – Lawrence of Arabia – was one model for *Dune*'s hero, Paul Atreides.

DUNE IS OFTEN LAUDED AS A PIONEERING WORK OF 'ECOLOGICAL SCIENCE FICTION'...

You can see that Arrakis – the planet in *Dune* – is an ecology. It's got fairly simple elements but it does actually fit together as a living entity in an authentic way. And where Herbert may have really been a pioneer is showing this complete working world with a reasonably plausible ecology as a single vision. You could argue that it's like a precursor of the astronaut photographs of the Earth and the Moon – seeing the whole Earth as a system. *Dune* was published in 1965, a few years before those photos emerged in 1968 with Apollo 8. I think the world was ready for that. We were going to the Moon, we were ready to look back at the Earth and Herbert caught the zeitgeist there.

WHAT NOTABLE SCIENCE FICTION WORKS HAS DUNE SINCE INSPIRED?

Certainly *Star Wars*. I think with George Lucas it's not just the galactic empire stuff, but he seemed to love



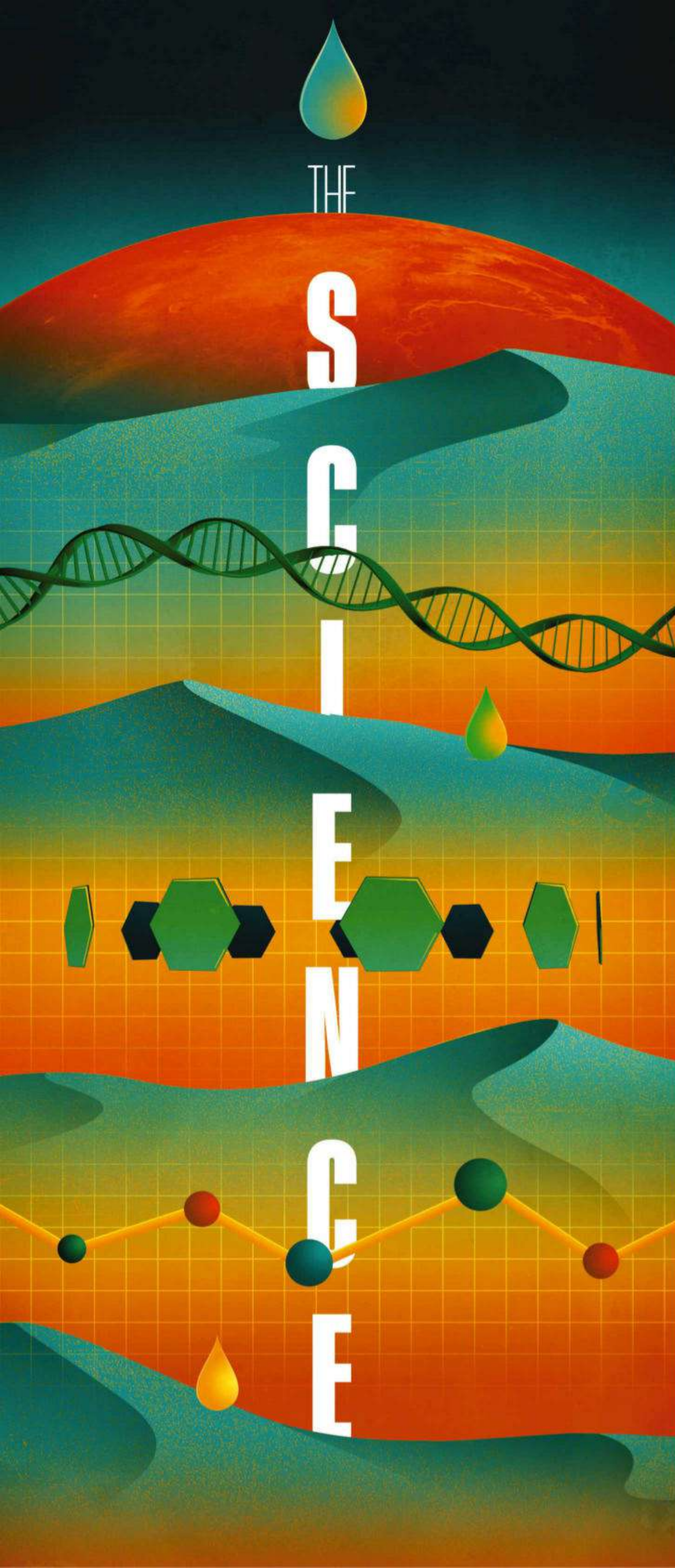
desert visuals. Tatooine in *Star Wars* is a version of Arrakis in a way. But also there's the other side of *Dune* – the telepathy and the messianic, superhuman side. Once again there were these in *Star Wars*, humans with superhuman powers that they have to discover and master.

Also, the work of Ursula Le Guin perhaps. Her novel *The Word For World Is Forest*, published in 1972, is *Dune* with trees. Later on is Kim Stanley Robinson's *Mars* trilogy – all about ecologies and building ecologies. And space opera has definitely continued to prosper since *Dune*. Nowadays, it's stronger than ever.

ABOVE Frank Herbert wrote *Dune* at just the right time – public interest in space exploration and other planets was just starting to build

STEPHEN BAXTER

Stephen is an award-winning science fiction author and vice-president of the HG Wells Society. His latest book *Galaxias* (£20, Gollancz) will be out on 21 October.



STRANGER THAN FICTION

***Dune* isn't just a book or a film, it's a beautiful universe built on hundreds of tiny ideas. Here we explore the modern scientific parallels of the ideas at the heart of this epic movie.**

COULD WE MAKE A SUPERHUMAN?

Paul Atreides, the hero of *Dune*, discovers that he has been gifted with incredible, superhuman powers – such as precognition and omniscience. This is no accident. Paul is the result of painstaking genetic engineering and selective breeding over many generations by an organisation known as the Bene Gesserit.

The question is: could you, in the real world, breed, or genetically edit, a 'chosen one'?

In November 2018, the world was shocked by news that the first gene-edited human babies had been born in China. According to He Jiankui, the rogue scientist behind the project, the twin girls' genetic make-up had been tweaked to give them innate resistance to HIV – because their father was HIV-positive.

This was done using a gene-editing technique called CRISPR-Cas9. This is essentially a genetic version of the search-and-replace in



“Genes don’t work in a simplistic way for most of the complex traits people might want to breed selectively for, and genes also interact with the environment around them”

your word processor, which can scan a genome for a target chunk of genetic code and then replace it with a new custom sequence.

He has since been sentenced to three years in prison for breaching Chinese laws that ban the application of gene editing to human embryos. At present, only a small number of countries permit this, and nowhere is it legal for such embryos to be implanted in the womb. But as the technology matures this could change.

“Within 30 years, it will probably be possible to make essentially any kind of change to any kind of genome,” says Prof Jennifer Doudna, of the University of California, Berkeley, who shared the 2020 Nobel Prize in Chemistry for her role in the development of CRISPR. “You could imagine that, in the future, we’re not subject to the DNA we inherit from our parents, but we can actually change our genes in a targeted way.”

Naturally, such modifications would be confined to the treatment and prevention of disease, and enhancing human capabilities, such as strength and intelligence, rather than endowing the subject with superhero powers. Even so, reservations remain.

“The problem with gene editing is that genes don’t work in a simplistic one-to-one way for most of the complex traits people

ABOVE Sandworms expel oxygen, making the atmosphere on Arrakis breathable to humans

BELOW The rugged desert world of Arrakis has no water, so the Fremen inhabitants have adapted their culture and way of life to survive on this harsh planet

might want to breed selectively for, like strength, beauty and intelligence, and genes also interact with the environment around them,” says Angela Saini, author of *Superior: The Return Of Race Science*. “More fundamentally, why would we want to do it at all? My ideal world is one in which we accept all people in their glorious, messy diversity as they are.”

COULD WE TERRAFORM A WORLD?

Dune is the informal name for the planet Arrakis, a rugged desert world located in the star system Canopus and where much of the story unfolds. Its two main inhabitants are a tough group of people called the Fremen, and the native Shai-Hulud – a species of giant sandworm that lives for thousands of years and can grow to more than two kilometres in length. ●





“With a Fremen suit in good working order, you won’t lose more than a thimbleful of moisture a day...”

be drunk through a tube. Urine and faeces go to the thigh pads, from where water is similarly reclaimed. The suit is powered by the walking action of the wearer. As the Fremen leader Liet Kynes puts it, “With a Fremen suit in good working order, you won’t lose more than a thimbleful of moisture a day...”

Nothing quite like a stillsuit exists in the world today, because there’s not a great need for it. In space, however, the story’s quite different. On the International Space Station (ISS) there is no natural source of water. Any new water brought to the station has to be launched on a rocket from Earth, at a cost of several thousand dollars per litre. And for that reason, the station employs a closed-loop water purification system, similar to the Fremen stillsuits, albeit on a slightly less personal scale.

The ISS system is able to recycle up to 93 per cent of the water used by the astronauts

ABOVE LEFT Phototrophic bacteria could be used to introduce oxygen to the atmosphere of Mars

ABOVE Paul Atreides, the main character in *Dune*, with his mother Lady Jessica Atreides

● The major diet of the Shai-Hulud is sand, supplemented with tiny organisms known as sand plankton. As they digest this rather bland fare, their metabolism releases oxygen – which perhaps isn’t so far-fetched given that sand is just silicon dioxide (an atom of silicon bonded to two atoms of oxygen). And this gives Arrakis an atmosphere that’s breathable to humans.

On Earth, we owe our breathable atmosphere to photosynthesis by plants and bacteria. These take in carbon dioxide and water, combine them with sunlight to create food for themselves in the form of sugars, and give out oxygen along the way. Humans – and animal life in general – could not have evolved on Earth had it not been for the Great Oxygenation Event between 2 and 2.4 billion years ago, when photosynthesising cyanobacteria living in the planet’s early oceans spewed oxygen into the atmosphere.

“This culminated in an atmosphere that could support metazoans [multicellular organisms] around 540 million years ago and then us somewhat later,” says Prof Gary King, of Louisiana State University.

King is researching the possibility of using photosynthesising bacteria – also known as phototrophs – to introduce oxygen into the atmosphere of Mars. This process of engineering an alien world to make it more like our own, and potentially habitable by humans, is sometimes known as ‘terraforming’.

In 2012, NASA’s Curiosity rover found direct evidence for the presence of water on Mars – a key ingredient for photosynthesis. Most of the water is frozen solid, however. One way King’s terraforming plan could work is by building automated factories on Mars that generate greenhouse gases to warm the planet and melt the ice into a usable liquid form.

“Conceivably, Mars’s temperature could be raised enough to support phototrophs. But that still leaves challenges,” says King. One potential issue is the stream of high energy radiation pouring from the Sun. On Earth, we have a magnetic field to bat away these particles. But Mars has no such protection, and this is thought to be how the planet’s original atmosphere got blasted away – a process called ‘spallation’ – some 3.5 billion years ago. How do you stop the same thing happening again? King believes that once microbes have established an active biosphere on Mars, then oxygen production may be able to keep pace with the spallation losses – in much the same way that plants on Earth keep pace with the consumption of oxygen by animals and other aerobic life.

COULD WE SURVIVE ON A WATERLESS WORLD?

Deserts aren’t the most hospitable locations, but *Dune*’s Arrakis is especially harsh. Rain never falls on this desolate planet, and its human population, the Fremen, must resort to some resourceful tactics to survive. One of their innovations is the stillsuit, a full body suit that’s designed to recycle all moisture excreted by a human. Perspiration passes through the porous inner layers of the suit, to be filtered and collected in pockets from where it can



LEFT Stillsuits filter and purify water produced by the body so that it can be drunk

ABOVE The sun on Glossu Rabban's home planet, Giedi Prime, is obscured by pollution, giving the inhabitants a pale complexion

ABOVE RIGHT A portable force field is created by a generator worn on the belt, protecting the wearer from fast-moving projectiles

on board. That includes moisture from the air, secreted by sweating and breathing, as well as waste washing water and urine – which is purified by distillation then centrifuged to eliminate further impurities. All waste water is passed through further treatment and filtration processes to eliminate toxins and microorganisms. The purity is then tested electrically, and any water not making the grade gets processed again. It may come with the yuck-factor, but the drinking water on the ISS is purer than what comes out of most domestic taps.

Similar water-preservation measures are likely to be employed on Mars, where



usable liquid water will be scarce. Other measures on the Red Planet could include water harvesting from the atmosphere, or using condensers to turn vapour in the atmosphere into liquid water suitable for drinking.

A research paper published in 2018, in the journal *Environmental Science & Technology*, detailed a trial of such a system in Saudi Arabia. It used 35 grams of a moisture-absorbing gel to extract 37 grams of water overnight at a humidity of 60 per cent.

“This technology provides a promising solution for clean water production in arid and land-locked remote regions,” the authors of the study reported.

COULD WE MAKE A FORCE FIELD?

In the *Dune* universe, a Holtzman shield is a portable force field capable of protecting an individual soldier in battle. Created by a generator worn on the belt, the shield is able to deflect speeding projectiles away from the wearer, although slow-moving objects, such as a knife in hand-to-hand combat, can penetrate the barrier.

Force fields like this are a tall order in the real world. There are four known fundamental forces of nature – gravity, electromagnetism, and the strong and weak nuclear forces that exist within atomic nuclei. Of these, gravity is too weak to be useful as a localised force field – it takes all the gravity produced by our planet, the Earth, to stick our relatively puny bodies to its surface. On the other hand, the nuclear forces can be strong but, as the name suggests, they are confined within the minuscule cores of atoms.

Physicist Prof Jim Al-Khalili, of the University of Surrey, thinks it may one day be possible to build a force field based on electromagnetism. It's certainly a stronger force than gravity, with a longer range than the nuclear forces. However, it only exerts its influence on bodies that are electrically charged. So the first job upon detecting an incoming projectile would be to charge it up. This could be done, Al-Khalili believes, by bombarding the object with a beam of positrons. These are particles of antimatter, of equal mass to the electrons that orbit around the outside of atoms, but with opposite electrical charge. When positrons and electrons come together they totally annihilate one another. He speculates that this effect could be exploited to charge up an inbound projectile so it can be deflected.

“You can use positrons to destroy electrons in the target,” he says. “And if you destroy enough of them then the target becomes positively charged. Then you can whack on an electric or magnetic field to deflect it.”

Although plausible, this is still most likely a technology reserved for the far future – indeed, it's probably just as well that the action in *Dune* doesn't take place for another 20,000 years.

One concept that is being developed now is electric armour for battle tanks. Ordinarily, a tank relies on hefty steel plates to deflect incoming bombs, missiles and gunfire. But the new idea means switching the thick armour for two thinner metal plates separated by an insulating layer. The plates are electrified ●

• from a power source so they act like a high-power capacitor, able to store up a huge electrical charge because of the insulator between them.

“When a metal projectile penetrates the outer layer and impacts on the second, it closes the circuit and allows a massive amount of power and energy to be dumped into the projectile,” says James Bingham, a military analyst. “This destroys the projectile or offsets its kinetic energy and penetrative effects sufficiently to mitigate its destructive impact.”

This makes for armour that’s highly effective and much lighter than usual, giving armoured vehicles greater speed and manoeuvrability. Electric armour is currently under development at the UK’s Defence Science and Technology Laboratory.

WOULD WE RULE THE COSMOS?

The *Dune* universe seems to be dominated by a single species: humans. Contrast that

with, say, *Star Wars* – think of that infamous cantina scene – and you might wonder if Frank Herbert’s masterpiece is struggling to meet its diversity quota.

Of course, the *Dune* saga is set some 20 millennia in the future, and it’s not unreasonable to suppose that by then humans will have travelled to every corner of space. But still, you have to wonder where all the other indigenous races are. With the exception of the sandworms on Arrakis, and one or two other fleeting examples, we see very few. Could it be that our species is the principal indigenous race in the Universe – that *Homo sapiens*, or something close to it, has evolved independently on multiple other worlds?

The late evolutionary biologist Stephen J Gould found this idea preposterous. He argued that if you re-ran evolution here on Earth – never mind on some bonkers planet 300 light-years away – then the probability of getting humans a second time round is vanishingly small. His reasoning was that evolution is driven by random sets of genetic mutations, modulated by random environmental effects, such as mass extinctions, and that it would be extremely rare for the exact same set of effects to crop up twice.

But it’s a view that’s not universally held. One school of thought, called ‘convergent evolution’, says that random effects eventually

BELOW Liet Kynes, the main peacekeeper on Arrakis, has blue-stained eyes, due to constant exposure to spice melange excreted by sandworms

“One can say with reasonable confidence that the likelihood of something analogous to a human evolving is really pretty high”



average out so that evolution converges, tending to produce similar organisms in any given environment. For example, flight has evolved independently on Earth at least four times – in birds, bats, insects and pterosaurs. Eyes may have evolved as many as 40 times.

One adherent of this view is Prof Simon Conway Morris, of the University of Cambridge. “Convergence is one of the best arguments for Darwinian adaptation, but its sheer ubiquity has not been appreciated,” he says. “One can say with reasonable confidence that the likelihood of something analogous to a human evolving is really pretty high. And given the number of potential planets that we now have good reason to think exist, even if the dice only come up the right way every 1 in 100 throws, that still leads to a very large number of intelligences scattered around, that are likely to be similar to us.”

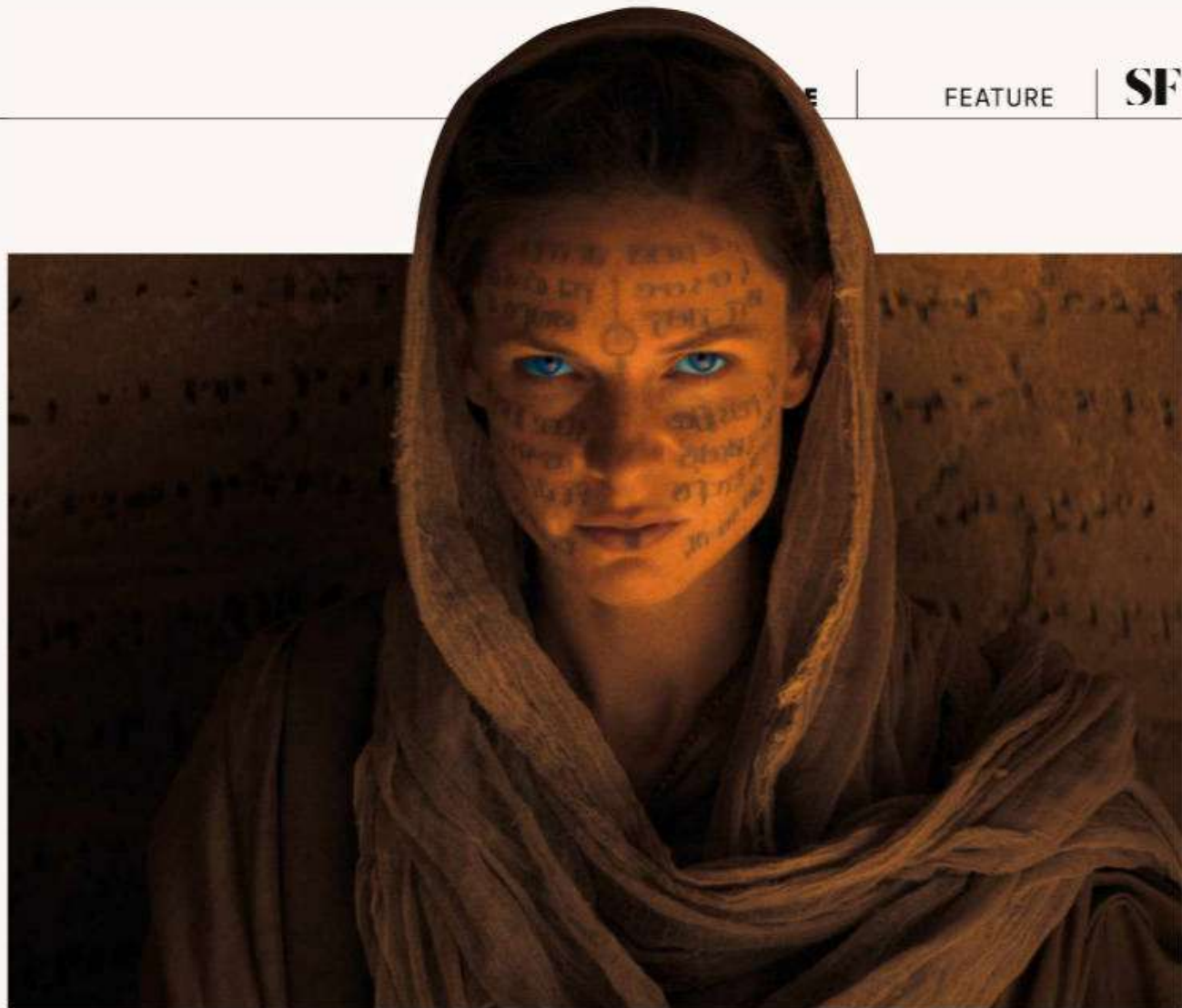
COULD WE MAKE SMART DRUGS?

Spice melange, usually just referred to as ‘the spice’, is a valuable narcotic substance, formed exclusively in the sands of the planet Arrakis from the excretions of young sandworms.

The spice confers health benefits, for example increasing life expectancy. It’s also highly addictive, creating a vast demand and making it an extremely precious commodity. Whoever controls the spice inevitably holds control over every other faction in the *Dune* universe. This may have historical parallels in the real world. As science writer Dr Carol Hart noted in her chapter on melange in the 2008 book *The Science Of Dune*, “In pre-Columbian America, the coca leaf was, somewhat like melange, largely reserved for the noble and priestly classes of the ancient Incas. In fact, the ruling classes retained their power in part by their monopoly on the coca leaf.”

Spice also has dramatic mind-altering properties, enabling a post-human species known as the Guild Navigators to see across vast swathes of space in order to guide spacecraft on long interstellar journeys. The Navigators live in tanks, continually inhaling orange spice gas in such quantities that it grossly mutates their bodies.

Even moderate exposure to the spice stains the entire eye of the user a deep dark blue, a trait seen in the Fremen people of Arrakis,



due to their constant exposure to the substance – and perhaps not unlike the persistent pupil dilation that can accompany real-world recreational drug use.

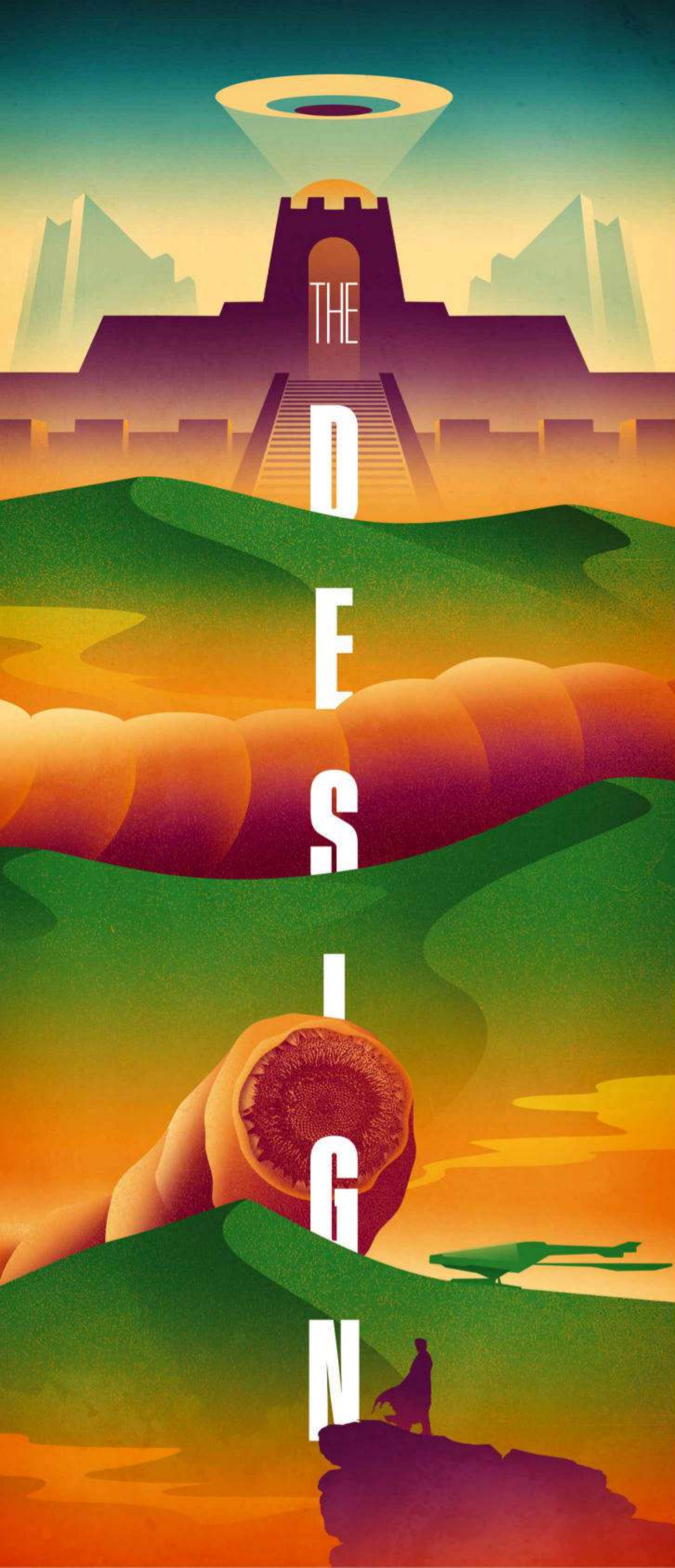
The Bene Gesserit are also avid spice users. It imbues them with the power to see into the future – and heightens their mental abilities, which in a loose sense might mirror the rise today of nootropic drugs, ‘smart pills’ taken by those seeking a mental edge. Their makers claim the drugs can improve cognitive functions like memory, attention, creativity and motivation. Indeed, they are sometimes prescribed to treat conditions such as ADHD and dementia.

Yet there is concern over the non-prescription use of nootropics. A 2020 study by the Harvard Medical School in Boston, Massachusetts, found that these ‘supplements’ can contain drugs not yet approved for pharmaceutical use. “Use of these supplements poses potentially serious health risks,” says study author Dr Pieter Cohen.

ABOVE The Bene Gesserit organisation use spice melange (pictured) to allow them to see into the future

DR PAUL PARSONS

Paul is a science writer based in the UK. His latest book is *The Beginning And The End Of Everything* (£12.99, Michael O’Mara Books).



STRIKING A CHORD

As the film's production designer, **Patrice Vermette** is responsible for the look and feel of *Dune*, building the world that the characters move through. He speaks to **Daniel Bennett** about how you create a sci-fi world from the pages of a book.

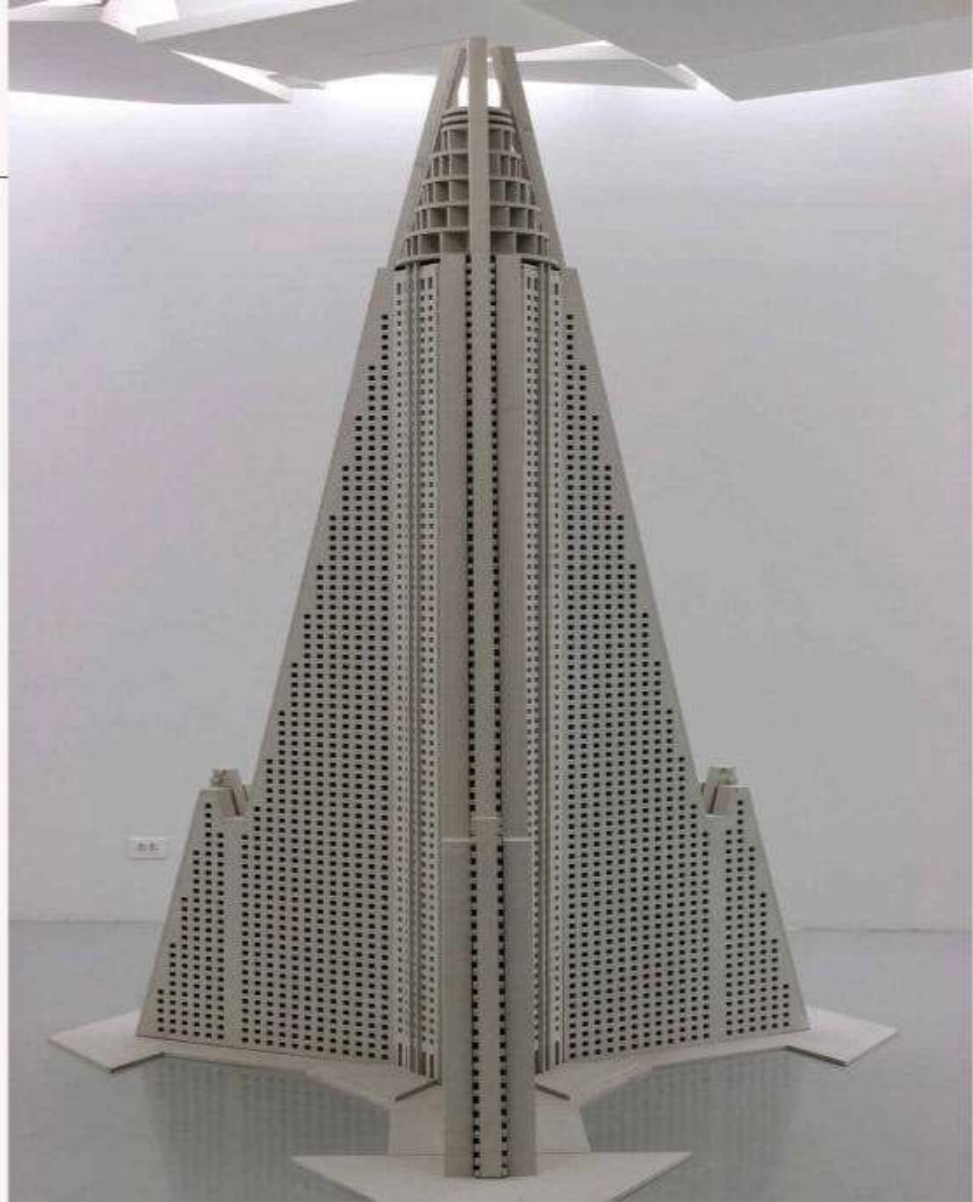
WHERE DO YOU START WITH A FICTIONAL UNIVERSE AS BIG AS *DUNE*?

It could have been overwhelming. But I always look for the angle of attack. It's like going skiing. You can see the slope: it's very, very steep and you could either decide to go straight down, or you can slalom down.

If you've read the books, you'll know there's enough description to point you in a good direction, but then again it doesn't dictate what the world should be, so you can make it your own.

I started collecting images from research, illustrations from books, the internet, little scraps and so on. From there, I exchanged with Denis [Villeneuve, the director], and we played tennis with our ideas. Once we found the right tone we started drawing and then hired some concept artists who worked off the reference boards. These mood boards give us the tonality of where we want to go architecturally and in terms of scale. It can be an extremely bizarre collection of images sometimes. So we start off very wide and then we will zoom in to the finer details.

It's great to work with Denis because once he agrees on something he likes, he never changes his mind, he'll never go back. You're certain you can keep digging in a direction and that will be the right direction. That allows us to go deeper and deeper into the design, we'll never have to reinvent anything.



SO WHAT WOULD WE FIND ON THE DUNE MOOD BOARDS?

The first thing I remember Denis showing me was a board of Richard Avedon photography, which was great for the softness of the mood. And we shared images of bunkers from WWII; images of ziggurat architecture from Mesopotamia; brutalist architecture from the ex-Soviet bloc and also Brazilian brutalist architecture. That was for Arrakeen [the main city in Arrakis, the planet on which *Dune* is mostly set]. We talked about how the colonialism always tries to force itself onto a landscape, which led me to the work of Nicolas Moulin and of Super Studio in the 1960s, both concept architects who had these designs for huge human-made constructions jutting out of landscapes, which were kind of terrifying. I think that imagery resonated in what we wanted to create in the world of *Dune*: the sense of scale, and a sense of imposing yourself on a place, and the idea that these structures can show the power of a nation. That was very important for us.

After that we started thinking about the landscape itself, and the natural elements of each planet in the book. Arrakis has winds of up to 850 km/h (530mph) that would tear the pavement off the ground. So, I try to think like an architect or a city planner building this place. Oh yeah, and there's this big worm...

You have to be true to the nature of things, the elements of the planet. So I

THIS PAGE To create the *Dune* world, production designer Patrice Vermette and director Denis Villeneuve drew inspiration from WWII bunkers (above), the work of architect Nicolas Moulin (above right) and ziggurat architecture (right)



PATRICE VERMETTE

Patrice is a production designer who worked with Denis Villeneuve on Arrival, arguably one of the best science fiction films of the last decade. He's also worked on blockbusters like Sicario and Prisoners.



would start by setting the foundation of a city on Arrakis in a natural protective environment, which would probably be a mountain bowl. There you have protection from the wind, and the rocks would stop the worm from penetrating. And then you create very angular structures so the wind can just slip past the structure as opposed to smashing right into these buildings.

The weather was another thing that stuck from the beginning. Both Denis and I are French Canadian and fall [autumn] is our favourite season. It's not too warm, it's not too cool. It's the perfect weather. It's change, it's the end of something. We're headed towards the death of a year and the beginning of a new cycle. So for Caladan [Paul Atreides's home planet] we felt that was the perfect weather. The perfect background.

WHAT CREATION WERE YOU MOST EXCITED TO SEE AS A FINAL PRODUCT?

Firstly, I was excited to see that it all worked together. I was worried we might have gone overboard. But I'm so happy for it now. I think one of the biggest moments was when we landed 🎬



► the ornithopters [dragonfly-like spaceships]. It was a company from England called BGI who built them. Just like in [the film] *Arrival*, our approach is to be as physical as possible. We flew two of them in the film.

WHAT WAS THE HARDEST THING TO REALISE?

I think the ornithopters and the worm are part of the mythology and they're the elements that the fans are expecting to see. The fans will have their own interpretation of it. So you have to be careful with what you do. They needed to be real looking. For Denis and I the approach has always been that to believe in something extraordinary, you need to anchor it in normality. So that's why we didn't use any green screen or blue screen.

We use other tricks, but we tried to build as much as possible. Green screen takes people out of the moment on the set, so we created new tricks with the help of Paul Lambert, our brilliant visual effects supervisor.

For example, on set we needed to create the right light [without using a green screen]. So we built sets 20 feet [six

“For me, good science fiction is a way to reflect, to mirror our society. To just talk about where we are as human beings”

metres] high, and then where the set ended we extended it with fabric, so that the light would fall the right way [and the sets would feel realistic].

YOU HAVE DAVID LYNCH'S ORIGINAL *DUNE* HANGING OUT IN THE BACKGROUND, WHICH I GUESS WAS A BIT OF A MISSTEP FOR LYNCH. WAS THAT IN YOUR MIND WHEN YOU MADE THIS FILM?

For me, Lynch's movie did resonate, but I didn't relate to it. But what I really appreciated was the production design of it.

After *2001: A Space Odyssey*, the aesthetic of almost every sci-fi was derived from that film, maybe a bit more battered or beaten up. Stylistically, *2001: A Space Odyssey* traced the outline of what sci-fi should look like. But there were a couple of films that went outside the box. *Dune* was one of them. So I appreciated the design, but I didn't want to do anything close to it.

ABOVE Arrakis's enormous sand-gobbling worms needed to be recreated successfully, as they are such an iconic part of the story



YOU WORKED ON *ARRIVAL* WITH DENIS, WHICH WAS ONE OF THE BEST FILMS OF THE LAST DECADE. AND I'D SAY THAT LOOKED AND FELT DIFFERENT TO TRADITIONAL SCI-FI TOO. THE ALIENS, THEIR LANGUAGE, THEIR SHIP: ALL UNIQUE. IS THAT WHAT YOU AND DENIS SET OUT TO DO?

Absolutely, Denis thrives on that. It's good to have references, but at some point we need to close the book and let our imagination guide us. There's nothing more discouraging for a designer than when a director says, "I saw this in that movie, can we do something very similar?" It's the most anticlimactic thing you can say to a designer. Let's try to do something original, we may not succeed but at least let's try.

WHAT SCIENCE FICTION HAS ANCHORED YOU IN TERMS OF WHAT YOU LOVE?

Well my mother doesn't get sci-fi. She only sees the surface of it.

TOP Green screens were eschewed to make the *Dune* universe feel as real as possible

ABOVE LEFT The ornithopter craft were built by British company BGI

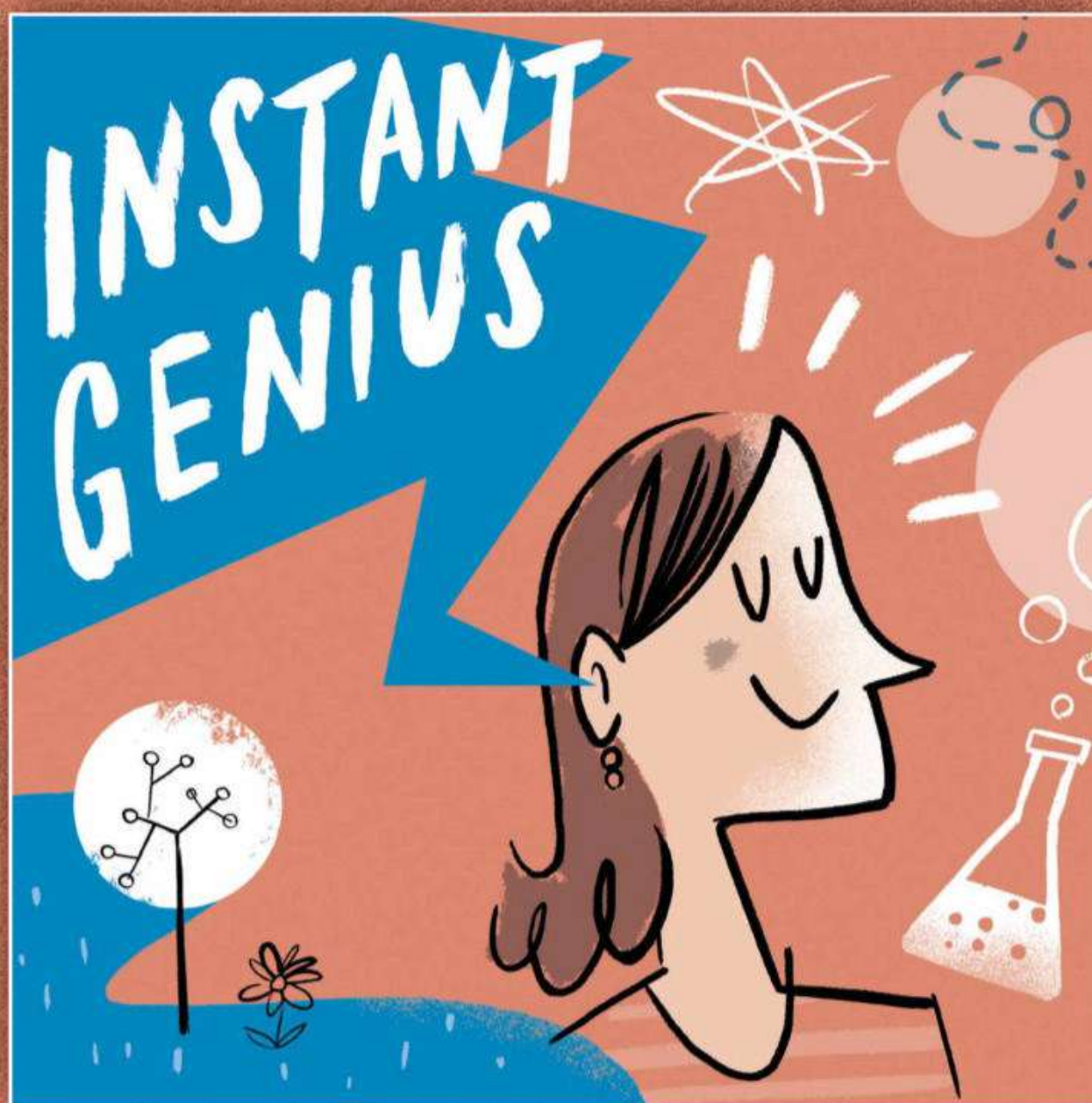
ABOVE RIGHT 2016's *Arrival*, also created by Denis Villeneuve and Patrice Vermetti, is one of the decade's best sci-fi films

For me, good science fiction is a way to reflect, to mirror our society. 'Détourné', as we say in French. To just talk about where we are as human beings. I think *Dune* is the perfect book for that matter as it talks about colonialism, imposing ourselves on other cultures, our exploitation of natural resources and the way we've been treating the planet and each other. When you see Giedi Prime [The home planet of the Harkonnens] it's where we're heading.

It's entertainment, but at the same time if there's a small part of reflection we can have on ourselves, sci-fi is the perfect vehicle for that. It's almost subliminal. **SF**

DON'T JUST READ THIS MAGAZINE... LISTEN TO US TOO

The all-new weekly podcast from the team behind *BBC Science Focus*



FEATURING



THE BIG BANG
with **Prof**
Jim Al-Khalili



THE NEANDERTHALS
with **Dr Rebecca**
Wragg-Sykes



CALORIES
with **Dr**
Giles Yeo



FORENSICS
with **Prof**
Sue Black

BBC
SOUNDS

The new series of
Just One Thing started
on 29 August. Listen or
download at [bit.ly/
BBC-one-thing](https://bit.ly/BBC-one-thing)

COMMENT

IT'S BETTER OUT THAN IN

The Mediterranean diet will increase flatulence, but it has benefits for you and the planet

I am a big fan of the Mediterranean diet, which is rich in oily fish, nuts, vegetables and legumes (such as lentils and red kidney beans). There's a lot of research showing that this way of eating reduces your risk of heart disease and type 2 diabetes. And we also know that switching from a typical Western diet to a Mediterranean diet can be an effective way to improve your mental health, with studies showing that it reduces rates of anxiety and depression.

But there are a couple of downsides to the diet. Anyone who's started eating more fibre-rich food (or fermented foods, such as sauerkraut) will know that you soon start producing much larger stools and far more wind.

Now, thanks to scientists from the Liver and Digestive Diseases Networking Biomedical Research Centre in Spain, we know just how big the effect is. For their study, titled 'Differential effects of Western and Mediterranean-type diets on gut microbiota', they recruited 20 male volunteers and randomly assigned them to eating either a typical Western diet for two weeks followed, after a break, by a Mediterranean-style diet, or vice versa.

Towards the end of each phase of the study, the participants were

“But can you get the health benefits of the Mediterranean diet without the social discomfort?”

asked to fill in a daily questionnaire that asked, among other things, how often they had passed wind, how bloated they felt and the number, shape and weight of their stools.

Faecal samples were collected, to look for changes in gut bacteria and they had the volume of gas they produced accurately measured by collecting the gas (via balloons attached to the rectum) after eating a standardised meal of stewed beans.

So what did they find? Well, not surprisingly the change in diet had an impressive impact on the microbes living in the volunteers' guts, with a shift towards more butyrate-producing types. This is a good thing, because butyrate is a short-chain fatty acid that's a powerful

anti-inflammatory and also helps support the health of the gut wall. The volume of 'colonic biomass' (poo) increased by 60 per cent and the amount of gas also soared. They not only passed wind around seven times more each day, but each time they did it contained about 50 per cent more gas.

But can you get the health benefits of the Mediterranean diet without the social discomfort? Well, you might try eating seaweed.

A recent study published in the journal *PLOSOne* found that feeding cattle a particular type of red seaweed had a dramatic impact on the amount of methane they produced (at both ends). The importance of the study is that cattle (and other ruminants) have a big impact of greenhouse gas emissions, due to the amount of methane they produce, so anything that will cut their gas production has to be a good thing.

I've no idea if eating seaweed would have the same impact on humans, but I'm told that drinking seaweed tea, made by pouring boiling water over dried kombu seaweed, has a soothing effect on the gut. **SF**



**MICHAEL
MOSLEY**

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *COVID-19: Everything You Need To Know About Coronavirus And The Race For The Vaccine* (£6.99, Short Books).

BBC
TWO

COMMENT

THE NET IS NO SUBSTITUTE FOR FOLK WISDOM

Every culture on Earth, and even some groups of animals, have traditions and rituals for sharing knowledge vital for survival



ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.



Once a year in a small village deep in the mountains of Mali, members of the Mande community gather around the world's oldest balafon to hear the folk stories of their traditions. The sacred instrument, known as the Sosso Bala, is made of wood and looks like a xylophone. It transmits traditions from the 13th Century that keep this distributed community tethered together through space and time. The man playing and singing is a direct descendant of the original storyteller and king. He holds all the knowledge of their world and its history: a one-stop shop for everything to do with the Mande people.

Most of us don't have a musical instrument that ties us together, but we will have someone in our lives who's the keeper of the knowledge. Often it's a matriarch—a grandmother, a mother, a great aunt—who, out of interest or a sense of responsibility, keeps all our stories ready to tell upon request.

The stuff in their heads is amazing. Who did what to whom and when, possibly the reasons why, where and certainly how. This is translated from gossip to noble truths, and turns into fables that have cautionary outcomes and actionable points. The ones that

“Recently we discovered that this very human trait wasn't limited to humans”

are more generic are unfortunately known as ‘old wives’ tales’, a turn of phrase that diminishes their value as good advice throughout the ages.

The stories can be useful for dealing with all sorts of queries: how do I get rid of that stuff between my toes? How do you treat morning sickness? (Often followed by what's the best way to get a baby to sleep?) Sometimes they answer bigger questions: where do I come from? What's my moral compass? The stories provide an answer, but the questions don't often have a single answer to them. It's just useful to speak with someone who knows how things are done.

Recently, we discovered that this very human trait isn't limited to humans. Marine biologists, animal behaviourists and other researchers have documented cultural knowledge in other species; whale

pods returning to parts of the sea that they'd abandoned a generation before; monkeys that communicate hunting skills to their offspring. Folk knowledge is not only culture, it's also survival. This is why we do it.

Mostly we do it in small units. Families sharing around a dinner table, or around a balafon. Recently, folk knowledge has expanded to global networks interconnected by electronic wires. Look at any forum, particularly parenting forums, and you'll see folk knowledge at work and at play. It's exploded as we're trained to look for information online, rather than from within.

In this global folk wisdom experiment, what seems to have happened is that our questions can be more easily answered with misinformation. There are, after all, as many big questions seeking wisdom as small ones seeking solutions.

We don't gather once a year to reality check our folk stories. The Mande do, and their folk traditions, bounded by their culture and their practices, are realigned around a musical instrument. The internet has no reality except its own and, left unchecked, its wisdom has no rhythm. It's just chaos. **SF**



SPECIAL 100TH ISSUE OFFER

TRY 6 ISSUES FOR £10

when you subscribe to **BBC HISTORY REVEALED** today!

100



► A special price of £10 for your first 6 issues – just £1.67 per issue

► Save 70% off the shop price

► Treat yourself or a loved one to our action-packed magazine, **suitable for all members of the family**

► **Free UK delivery** direct to your door, at no extra charge!



SUBSCRIBE ONLINE OR CALL US



www.buysubscriptions.com/HRHA100



03330 162 116[†] Quote code **HRHA100**

[†]UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon–Fri, 9am–5pm. Overseas readers call +44 1604 973 723.

*6 issues for £10 is available for UK customers only paying by Direct Debit. After your first 6 issues, your subscription will continue at £19.99 every 6 issues, saving 39% off the shop price thereafter. You may cancel your subscription at any time. Your subscription will start with the next available issue. Offer ends 30 November 2021.





THE INSECT APOCALYPSE

The meadows are no longer buzzing, and our gardens are falling silent.
Prof Dave Goulson tells **Alice Lipscombe-Southwell** why our insects
are in decline and how we can help bring them back

WHY ARE INSECTS IMPORTANT, AND WHAT ROLES DO THEY PLAY IN THE ECOSYSTEM?

So many, it's hard to know where to start. Insects make up the bulk of life on Earth in terms of biodiversity. More than two-thirds of all species that we've identified are insects. Birds, other insects, bats, lots of small mammals, lizards and freshwater fish all depend on insects for food. If the insects weren't there, then they wouldn't be there.

But insects do a whole bunch of other important stuff too. Scientists call it 'ecosystem services', which is a bit of an unhelpful phrase. It's things like recycling, so maggots help to get rid of dead bodies, dung beetles help to get rid of cowpats, and other insects help to break down dead trees and leaves and other things. So they're really important in nutrient cycles. They keep the soil healthy. They move seeds around. They do all sorts of stuff.

I guess the thing that most people recognise is that insects pollinate. So roughly 87 per cent of all the plant species on the planet need pollinating by some kind of animal – occasionally, in the tropics, that animal is a hummingbird or a bat. But 99 per cent of the time it's some kind of insect.

Essentially, life on Earth would grind to a halt if we didn't have insects.

THERE ARE LARGE NUMBERS OF INSECTS DYING OUT. WHY IS THAT?

There are many drivers. You know, there's no single cause of insect declines, but probably the biggest one has been loss of habitats in the UK, things like our ancient woodlands, our heathlands, our fens and marshes, and our flower-rich meadows – most of them have been swept away. Obviously this isn't something

that's confined to the UK. In the tropics, we've got deforestation and so on. Essentially, we're replacing natural, biodiverse habitats with cities or monocultures of crops and that's had a huge impact. And associated with that is probably the second biggest driver of insect declines, which is the rise in the many different pesticides we use in farming, but also in gardens and in our streets.

But then there's a whole bunch of other things, such as invasive species, climate change, light pollution affecting nocturnal moths and so on. It's almost like a sort of perfect storm. You know, insects might cope with one or two things, but they can't cope with this whole blizzard of different adverse pressures on their populations.

I REMEMBER WHEN I WAS CHILD, IF YOU WENT FOR A DRIVE IN THE CAR THERE WOULD BE BUG SPLATS ALL OVER THE WINDSCREEN. I DON'T SEE THAT ANY MORE.

I've heard this from so many people, and it's the only aspect of insect declines that's really in the public consciousness. You know, people don't pay much attention to insects – most people aren't regularly looking out for them. But there was this phenomenon of having to stop to clean your windscreen, which I can remember from when I was younger. There was a time a few decades ago where the windscreen, the headlights, the grille and the whole front of the car was this mass of dried, splattered insect guts. And it just doesn't happen at all any more.

ARE WE SEEING THESE DECLINES IN INSECTS ALL OVER THE WORLD?

The long-term insect studies are biased towards Europe and North America, where there are lots of scientists, like me, that are interested in

PROF DAVE GOULSON

Dave is a professor of biology at the University of Sussex. He has been obsessed with insects all his life. He's spent almost 30 years specialising in bumblebees and founded the Bumblebee Conservation Trust. He has written a number of popular science books, his latest is Silent Earth: Averting The Insect Apocalypse (£20, Jonathan Cape). You can find his wildlife gardening tips on his YouTube channel, or follow him on Twitter @DaveGoulson

• insects. We have almost no data from Africa, South America and most of Southeast Asia, which is really worrying because that's where most biodiversity is. There were one or two studies from the tropics, which show pretty big insect declines, but for most tropical insects, we haven't really got any data. I'd be pretty confident that they're declining there, too, because we're seeing massive habitat loss and climate change and all these other environmental issues affecting those countries.

WHAT WILL HAPPEN IF WE LOSE THE INSECTS?

WHAT WILL THE FUTURE LOOK LIKE?

Life will be tough. Most of the fruits and vegetables we eat depend upon insects to give a good harvest. So if we lose pollinators, then it's going to be really difficult to provide a healthy diet to the growing human population.

But it isn't just pollination. I mentioned earlier that insects help to keep the soil healthy; we have major problems with soil degradation around the world. Soil health depends on all the little creatures that live in it and we need healthy soils to grow crops. We also need insects to recycle things like cow dung. It's absolutely vital that all the nutrients in cow dung get recycled.

There's actually a really interesting example of the importance of that. When we colonised Australia and we took cattle, there were no dung beetles in Australia that could cope with cow dung, as they were used to marsupial dung, which is really dry. The cowpats weren't being removed and were just drying into hard little plates. Eventually, the entire landscape was covered in a layer of cowpats and the grass couldn't go grow through. At one stage, 15,000km² of Australia was covered under dried cowpats. And so they introduced dung beetles able to cope with cow dung. That was one example of a very successful introduction. Some animal introductions have gone badly wrong, but the dung beetles that were introduced ate all the dung and now the grass is doing well, the nutrients are being recycled.

It just shows that we take it for granted that the insects are there and they're doing these things. And if they're not there, then that's when we notice the problems.

DO WE KNOW HOW MANY INSECTS ARE STILL OUT THERE WAITING TO BE DISCOVERED?

We've named 1.1 million species of insect so far, roughly. We find new ones every day. There are undoubtedly lots we haven't yet described, or haven't given any kind of name to. But scientists struggle to estimate exactly how



“Most insects haven't gone extinct, and they can breed really fast, so if you provide the right conditions for them, their populations recover quickly”

many there are. People have tried to estimate, and most of the predictions suggest that there are somewhere between a million and 10 million more insect species that we haven't yet named. Obviously, that's a huge range, so it's probably a more realistic to say there are four or five million more species.

But that means that we've only named about 20 per cent – it's absolutely astonishing that there are all these amazing creatures out there that we've yet to discover.

IS THERE ANYTHING WE CAN DO IN OUR DAY-TO-DAY LIVES TO HELP THE INSECTS?

You see these environmental issues, like the rainforest burning and you feel helpless. It's depressing. You wonder, “What on Earth can I do to help?” But with insects it's different.

ABOVE It's a dirty job... but without dung beetles to do it, crucial nutrients wouldn't get recycled and the world's soils would be in bad shape



They live in our gardens and local parks and in the road verges and, you know, they're everywhere. And even small things really do make a difference in the end. Most insects, thankfully, haven't yet gone extinct, and they can breed really fast, so if you provide the right conditions for them, their populations recover quickly, unlike pandas or tigers.

The obvious place to start, if you're lucky enough to have a garden, is to grow lots of bee-friendly and pollinator-friendly flowers. Grow some wildflowers, don't mow your lawn too much, and plant some flowering trees if you've got a big enough garden. A pond will support a whole range of insect life. A little bee hotel will work quite well for some solitary bees. Don't use any pesticides. It seems crazy to me that we spray poisons in our gardens and the councils spray them in our streets and so on.

Most things you can do are really simple and many of them involve doing less rather than more, like less mowing of your lawn, less spraying of pesticides, not being so tidy, allowing a few weeds to flower. And little things like these really do make a difference.

There are 22 million private gardens in the UK. So just imagine if most of them were insect- and wildlife-friendly. That would really make a difference. It would be kind of a national network of little patches of miniature nature reserves. That would be fantastic.

ABOVE Prof Dave Goulson offers a bumblebee a chance to give him a close-up inspection

DISCOVER MORE



ON THE PODCAST

Listen to our full interview with Prof Dave Goulson on the Instant Genius podcast.

MANY PEOPLE DISLIKE INSECTS, AND SAY, "WHAT'S THE POINT IN A WASP? WHAT'S THE POINT IN A MOSQUITO?" IS THERE ANY WAY WE CAN CHANGE PEOPLE'S MINDS ON THAT?

Well, I often say, "What's the point of people?"

There are different ways of trying to persuade people that insects deserve looking after. You can use the argument that they're important – they often do things that are valuable to us, even if we might not recognise them. Wasps, for example, are effective pollinators – many people don't realise that. They're also really good at pest control, they eat aphids and caterpillars on our crops.

But there are probably some insects that don't do anything useful at all and you can't create an economic, utilitarian argument to save them. But I think it's really sad to bring everything back to a species only being worth saving if it does something for us. It's incredibly selfish. These are creatures that have been on the planet for millions of years – much, much longer than we have. And, you know, whether they do something useful or not, whether we find them beautiful or not, surely they have as much right to be here as we do?

We should try to be more tolerant of nature and value it for its own sake. We live on this rock hurtling through space with a little crust of life clinging to its surface. I mean, the whole thing is absurd and unbelievable, really. As far as we know, there may be no other life in the Universe, or it may be so far away that we never encounter it – and certainly nothing like [the life here on] Earth. It's unique. It's our home. It gives us everything we could want. You know, it's beautiful. It's inspirational. It feeds us and all the rest of it. And we're not really looking after it terribly well. And I find that just completely extraordinary. How stupid are we that we don't look after our home and all of the creatures that live on it. All our fellow travellers on this rock hurtling through space, we should value them.

These little creatures deserve to live. I just think they're amazing, actually. The more time you spend looking at insects, the more you realise how fascinating and intriguing they are and how much there is we don't know about them, and we'll never know if we wipe them all out. There are all these millions of insects we haven't even discovered yet; who knows what secrets they have?

I find it terribly sad, the thought that there are species going extinct that we haven't even seen. Species that we'll never know existed – because they'll be gone. And that seems like a terrible thing. **SF**

GIVE YOUR HOME THE PROBIOTIC MAKEOVER

Bacteria aren't always bad. Some, like the billions that live in our guts, are vital for our health. So should we make our homes and cities more hospitable to these beneficial microbes?

WORDS ANDY RIDGWAY

For generations, we've dealt with the bacteria and other microorganisms we share our homes with in one way: wipe them out. By pouring or spraying something onto household surfaces we keep germs away and stay healthy. It's a tactic that many of us have ramped up during the pandemic to keep the SARS-CoV-2 virus at bay. But there's growing evidence that we need to take an entirely different approach to these microbes. While there's no doubt that some of the microorganisms that live among us are harmful (and nobody is suggesting that cleaning isn't a good way to keep the likes of SARS-CoV-2 out of our homes) there's growing evidence that many of them are actually doing us good.

The thing is, we've been unwittingly meddling with the microbes we share our living rooms, kitchens and outdoor spaces with, creating hostile environments for those beneficial bugs. It means that while the idea of using

probiotics in our bodies has been around for a while, soon we might be giving our homes and our cities the probiotic treatment too.

WHAT'S IN THE SOUP?

Research to characterise the invisible microbial soup that we live in has taken off over the past decade. In May 2021, the results of a giant research project that involved 900 scientists and volunteers taking swabs of the microbes living on ticket machines, railings and seats in subways, buses and trams in 60 cities around the

world was published. This audit of urban microbial life found no fewer than 10,928 viruses and 1,302 bacteria that had not been identified before.

The research, led by Prof Christopher Mason at Weill Cornell Medicine, in the US, showed that every city has its own unique microbial mix. So whether you live in London, Hong Kong or Paris, you're exposed to a different blend of microbes. ➤

30-40 million

The number of bacterial cells shed by each of us every hour



ILLUSTRATION: MAXIM USIK



❶ Before this came the Wild Life Of Our Homes project that was run by North Carolina State University, which showed that we each share our homes with 9,000 species of microbes. Other research has identified the microbes that live in everything from university dining halls to shopping centres.

This explosion in microbial exploration has been fuelled by advances in rapid gene sequencing as well as computing power. The global city microbial count required two supercomputers in Pittsburgh to crunch through the masses of data – eight trillion gene bases from microbes gathered via swabs.

“In the field of microbiology, we’re doing the equivalent of explorers going out and seeing what plants live on different continents,” says Noah Fierer, a microbiology professor at the University Of Colorado Boulder, who was involved with the Wild Life Of Our Homes project. “We’re just starting to get a handle on which types of microbes we’re exposed to on a daily basis. These could be in our food, in the air or in the water we drink. These could just be on surfaces you touch and then you chew your fingernails and put your fingers to your lips and so forth. But there’s a lot of work that needs to go from what you’re exposed to, all the way to how it affects your health.”

The thing is, while we’ve become very good at identifying the bacteria, viruses and fungi that make us sick, what we’re less good at, Fierer explains, is figuring out which ones are doing us good, because it’s not straightforward.

“It could be that if you’re exposed to particular microbes when you’re two years old, it trains your immune system so that when you’re 40, you don’t have allergies. That’s hard to figure out. Or it could be dose-dependent. For example, if you’re exposed to some of them, it trains your immune system in a good way, but if you’re exposed too many, it could be bad. Or it could be individual categories or combinations of microbes.”

There is, however, tantalising evidence that many microbes are quietly doing us a lot of good. While research into the health-promoting effects of specific microbes is still in its infancy, certain species of bacteria have been linked with improvements in our physical and mental health (see ‘Bacteria you want in your life,’ overleaf).

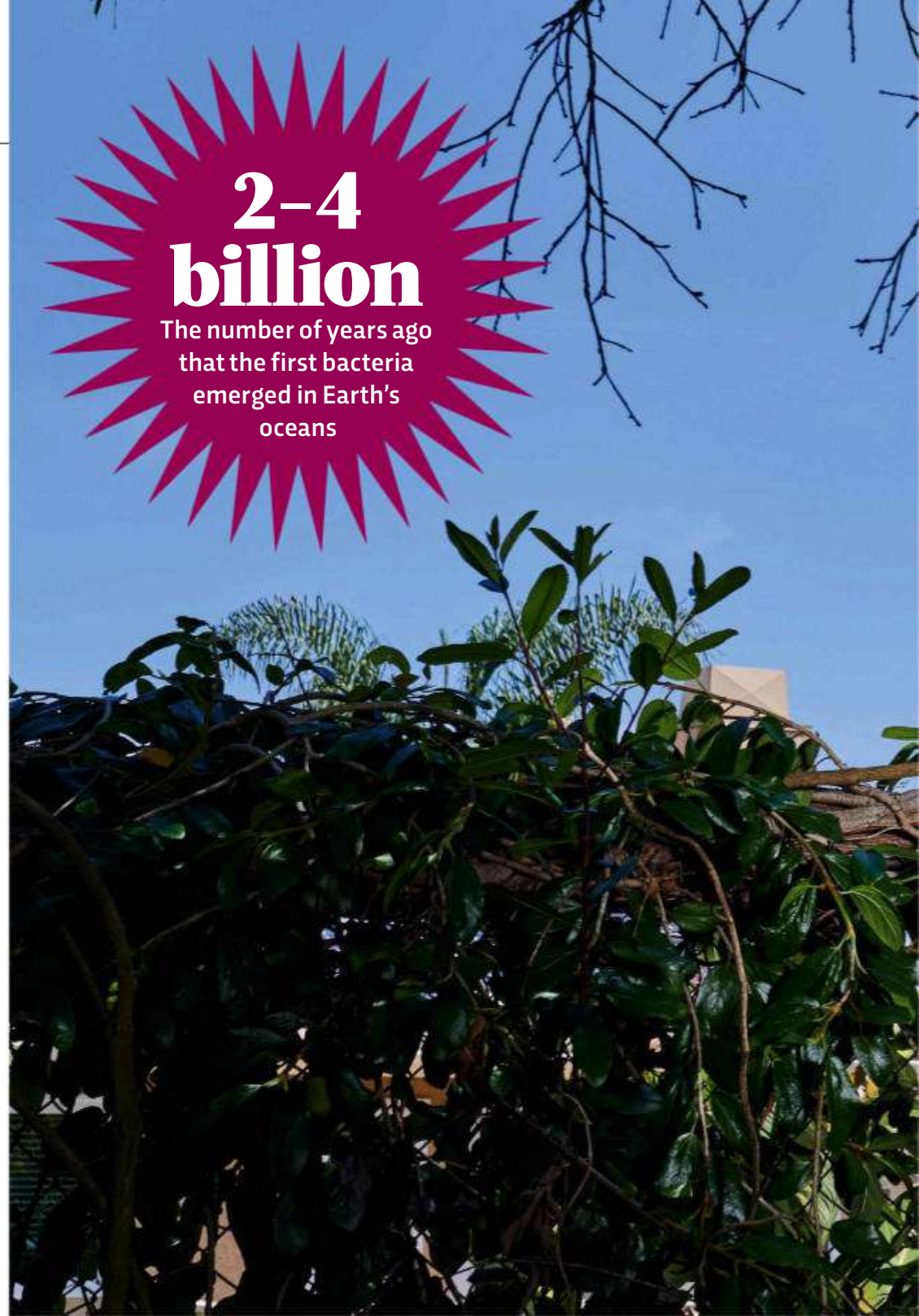
HOSTILE ENVIRONMENTS

Cities are diverse environments for microbes. “There are plants, dust, concrete, wood, glass, plastic and different types of bitumen versus stone,” says Prof Jack Gilbert, a microbial ecologist at the University Of California San Diego. Each of these represents a different environment, attracting different microbes. “[The city is] also quite inhospitable – the only place where microbes are going to thrive is where there’s lots of nutrients and moisture.”

The species of microbes that live on our pavements and park benches are very different to those that we’ve been exposed to for most of human history, which was spent in rural areas. “What we’ve experienced for most of our evolutionary history – so most of our time on this planet – is soil microbes and microbes that live on leaf surfaces, fruit and animals,” says Jacob Mills, a PhD student at the University of Adelaide, Australia. It’s the

2-4
billion

The number of years ago
that the first bacteria
emerged in Earth’s
oceans



ABOVE Prof Jack Gilbert is investigating areas where microbes thrive

RIGHT The antibacterial agents we use to clean our homes don’t discriminate between harmful and helpful bacteria

FAR RIGHT This coloured microscope image of house dust contains dog hair (dark brown), cat hair (orange), plant fibres (green) and dead skin (brown)





✕

“The species of microbes that live in our pavements and park benches are very different to those that we’ve been exposed to for most of human history”

microbes that live in soil and on plants that are most likely to be doing us good, training our immune systems as well as helping us to digest our food, control our weight and be mentally healthy.

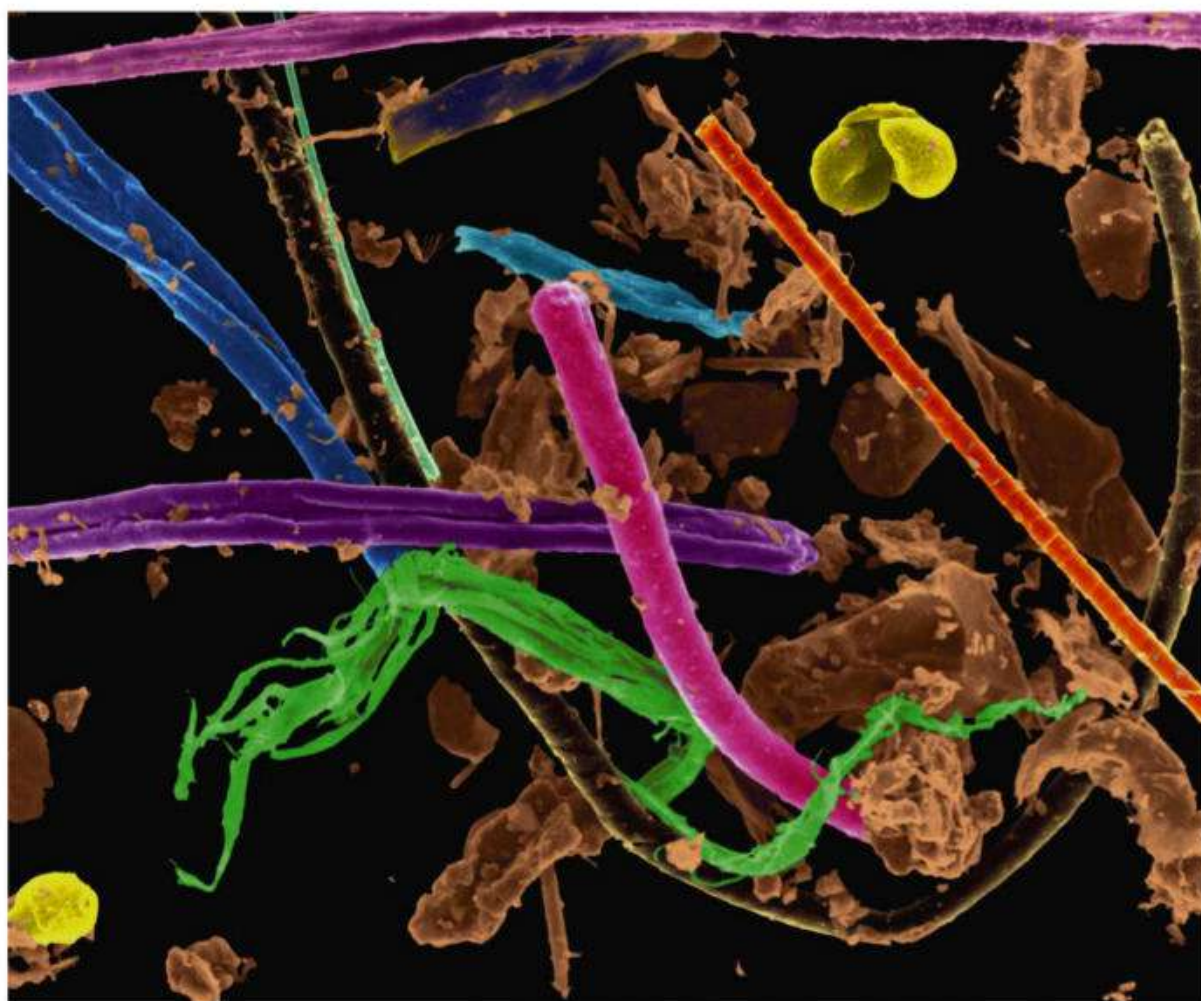
It’s a similar picture when it comes to microbes inside a building – whether it’s our homes or our offices. “It’s essentially a very cold, inhospitable environment. It’s like taking a rainforest and throwing it in the Sahara Desert,” says Gilbert. “There’s a rapid selection of microbial cells that have the ability to survive. So these are, if you will, like the mercenaries.” Some of these tough survivors can be harmful – they’re more likely to be ones that can cause disease and have some antibiotic resistance.

HELPING THE HELPFUL BACTERIA

The exact microbial cocktail we create in our homes is determined by a number of factors: whether or not we have a cat or a dog, how many rooms are carpeted, how warm and humid we like our homes to be and so on. The cleaning products we use have an influence too. “They’re undoubtedly altering microbe exposures, not just bacteria, but also fungi to some degree and viruses as well,” says Fierer. “Clearly if you have somebody in your household with some horrible gastrointestinal disease caused ➤

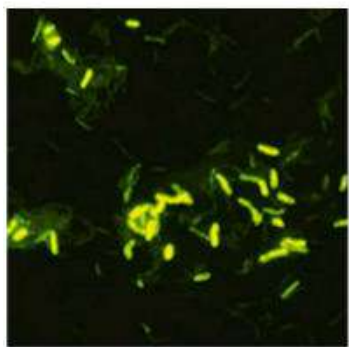


JOHN FRANCIS PETERS, MOMCLOG/GETTY IMAGES, SCIENCE PHOTO LIBRARY



THE BACTERIA YOU WANT IN YOUR LIFE

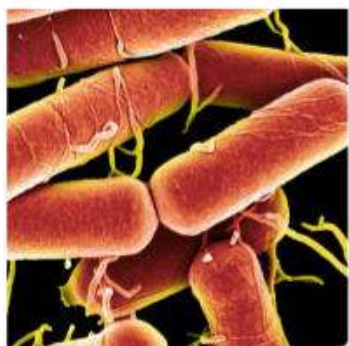
Research into the microbial good guys is still in its infancy, but it has already identified some helpful characters



THE STRESS RELIEVER

Mycobacterium vaccae was discovered on the shores of Lake Kyoga in Uganda in the 1970s by John Stanford, an immunologist. Today, Dr Chris Lowry, a neuroscientist at the University of

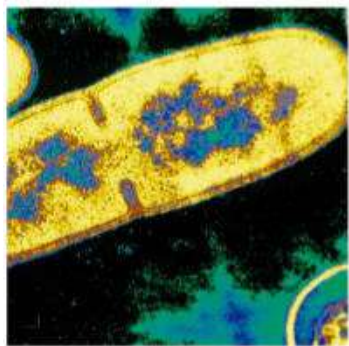
Colorado Boulder, has shown that this bacterium can reduce stress and anxiety – in mice, at least. Part of this effect is due to the bacteria controlling the expression of the gene *tph2*, which causes more of the mood-stabilising neurotransmitter serotonin to be produced.



THE IMMUNE BOOSTER

Bacillus subtilis is found in soil, and tests in animals have found it can supercharge their immune systems, boosting the antibodies in their circulation and increasing their ability to fight off infections

such as *Salmonella*. This microbe is already being used for good as it produces the antibiotic bacitracin, which is used as an ointment for skin and eye infections. It's also a hardy individual – its tough endospores have been found to survive for six years in space.



THE WEIGHT REDUCER

There are signs that another bacterium found in soil, *Bacillus licheniformis*, may help us keep our weight down. Tests in mice show that it can prevent obesity and it's thought that this is down

to some strains of the bacterium acting as factories for a substance called poly gamma glutamic acid. This biopolymer is also being investigated for its ability to kick a part of the immune system known as large granular lymphocytes (or 'natural killer cells') into action as a cancer treatment.



One billion

The number of bacteria found in a teaspoon of rich garden soil

► by a virus, you want to clean the hell out of the house. But we don't know the effects that cleaning your house has on the more beneficial exposures."

Our increasing knowledge about how we've transformed the microbial soup we live in, often in ways that aren't for the better, has led to growing interest in using probiotics for our homes – encouraging the microbial good guys and wiping out the bad guys.

Gilbert has been investigating how effective a probiotic spray might be that we could squirt onto places like kitchen worktops or office desks to kill microbes that are harmful. "The principal idea is to use strains of the genus of bacteria *Bacillus* that are benign to humans, but produce chemicals that kill off other bacteria," says Gilbert.

His lab in California is also developing 3D-printed surfaces that are porous and contain the right mix of nutrients to encourage good bacteria to grow. "We're looking at how to create more biologically friendly surface materials for everything from yoga mats, to walls and floors," says Gilbert. So soon the ultimate home decor might be a wall of health-giving microbes in your living room. But there's still work to be done to find the right nutrients and moisture levels that will allow the good bacteria to grow while preventing mould or fungi from taking hold. "We're at the cutting edge of what's technically feasible. But it's an interesting research area, trying to figure out how we



“There’s still work to be done to find the right nutrients and moisture levels that will allow the good bacteria to grow while preventing mould or fungi taking hold”

do this without causing some kind of rapid, runaway evolution that creates a superbug or allows fungus to grow everywhere and kill people,” says Gilbert. “So it’s a fine, delicate balance.”

Meanwhile Mills and other University of Adelaide researchers are looking at how we might enhance the microbial environment we’re exposed to in cities through ‘microbiome rewilding’. The idea is simple: bring the native plants and the wildlife back into cities and the microorganisms that are good for us will follow. “Hopefully you would create a more wild space in the urban area that would house the kind of microbes we co-evolved with,” says Mills. In practice, this would mean transforming parts of traditional Victorian-era parks, with their neatly cut grass

ABOVE LEFT Some strains of *Bacillus* bacteria are harmless to humans and could be used to kill off other bacteria

ABOVE Prof Christopher Mason and volunteers collect bacterial samples from subway turnstiles to audit some of the microbial life found in our cities

and select few tree species, into shrubby, forested areas with a wide variety of plants and animals.

But microbiome rewilding our cities isn’t without risks. After all, the pandemic has brought the ability of bad microbes to jump the species barrier into humans to the forefront of our minds. So bringing wildlife, with all the microbial baggage it carries, into our cities is risky and there are some balances to consider, says Mills. “The idea is that having microbial diversity is going to train immune systems and we’re going to have fewer non-infectious diseases, such as asthma, allergies, diabetes – all these things,” says Mills. “But is that going to increase the chance of infectious disease? It’s a question that’s going to take research to answer. I guess people with stronger immune systems are going to be able to handle infectious disease better. But it’s a very interesting tightrope to walk.” **SF**

by **ANDY RIDGWAY**

Andy is a journalist based in Bristol and senior lecturer in science communication at UWE Bristol

TRY 3 ISSUES FOR JUST £5*

WHEN YOU SUBSCRIBE TO

BBC music TODAY!

MAGAZINE



- RECEIVE YOUR FIRST 3 ISSUES FOR ONLY £5*
- AFTER YOUR TRIAL, CONTINUE TO **SAVE 20% ON THE SHOP PRICE** WHEN YOU PAY BY DIRECT DEBIT
- BUILD UP A LISTENING LIBRARY WITH A **COMPLETE WORK** ON EACH MONTH'S COVER CD

TRY
3 ISSUES
FOR JUST
£5!

🖱 subscribe online at www.buysubscriptions.com/MUHA21
☎ Or call 03330 162 118[†] and quote MUHA21

*This special introductory offer is available to new UK residents via Direct Debit only and is subject to availability. Offer ends 31st December 2021. The magazine used here is for illustrative purposes only, your subscription will start with the next available issue. After your first 3 issues, your subscription will continue at £25.15 every 6 issues thereafter, saving 20% off the shop price. Full details of the Direct Debit guarantee are available upon request.

[†]UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 9am to 5pm.

Q&A

YOUR QUESTIONS ANSWERED

... WHY DO PEOPLE BELIEVE IN CONSPIRACY THEORIES?
... ARE MOST MAPS OF THE WORLD WRONG?
... WHAT DOES A COMET SMELL LIKE?
... IS PINK A REAL COLOUR?
... HOW DANGEROUS IS IT TO WEAR A TIE?
... WILL PICKING MY NOSE AND EATING MY BOGIES MAKE ME ILL?
... DOES OUR SOLAR SYSTEM HAVE A WALL?
... DOES AN APPLE A DAY KEEP THE DOCTOR AWAY?
... CAN SMART TECH COMBAT CLIMATE CHANGE?
... DO ANIMALS GIVE EACH OTHER NAMES?
... WHAT'S THE BEST COUNTRY TO BE A PARENT?
... DO HUMANS HAVE A GENETICALLY INHERITED PREFERENCE FOR TASTE??

Email your questions to
questions@sciencefocus.com
or submit on Twitter
[@sciencefocus](https://twitter.com/sciencefocus)

OUR EXPERTS

NISHA BEERJERAZ
Astronomy writer

PROF PETER J BENTLEY
Computer scientist

PROF JON BUTTERWORTH
Physics lecturer

DR EMMA BYRNE
AI and parenting expert

MARCUS CHOWN
Physics journalist and author

DR ALASTAIR GUNN
Astrophysics lecturer

DR CHRISTIAN JARRETT
Neuroscientist and psychologist

DR NISH MANEK
Medical expert and GP trainee

STEPHANIE ORGAN
Human biology expert

DR HELEN PILCHER
Biologist and science writer

LUIS VILLAZON
Science and technology writer



ANDREW PETERS, LONDON

DO BUTTERFLIES RETAIN THEIR CATERPILLAR MEMORIES?

The transition from caterpillar to butterfly via a soupy pupal mashup remains one of the greatest mysteries of the animal kingdom. During metamorphosis, body parts are liquified and then reorganised, but the ability of memories to survive this process was unknown. That is until scientists trained caterpillars to avoid the

whiff of ethyl acetate by pairing the chemical, often used in nail polish remover, with a mild electric shock. When the larvae turned into adult moths, most continued to avoid the odour, suggesting that moths and butterflies may indeed remember some of their larval experiences. Yet another reason to be kind to caterpillars. **HP**

ILLUSTRATION: DANIEL BRIGHT



DEAR DOCTOR...

HEALTH QUESTIONS
DEALT WITH BY
SCIENCE FOCUS EXPERTS

I ABSOLUTELY LOVE PICKING MY NOSE AND EATING BOGIES! BUT WILL THIS MAKE ME ILL?

We've all watched distastefully as our toddlers' fingers creep towards their nose, dig around for a bogie, and whip it into their mouth. Of course, we would never do that ourselves. Not even when our cameras are turned off during a video conference. Never.

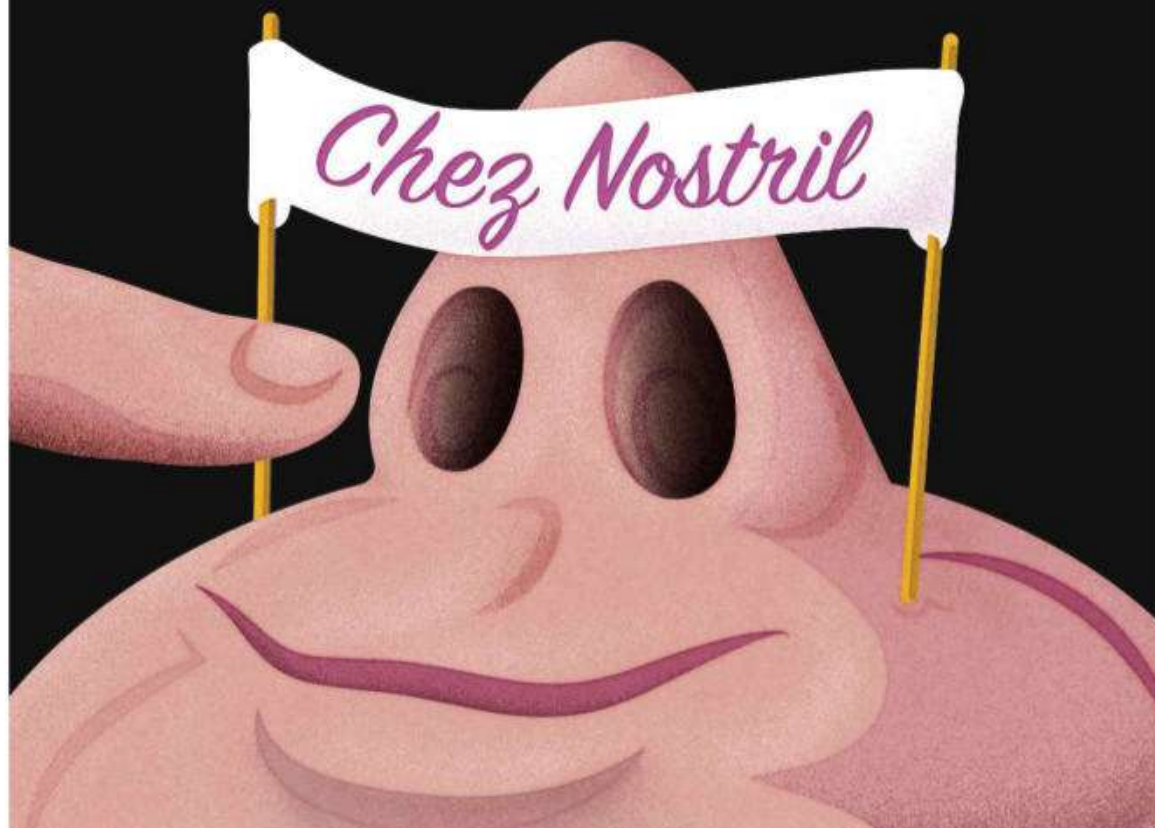
The technical name for bogie-eating is mucophagy, and when it becomes a true, obsessional habit, it is known as rhinotillexomania. But is this behaviour safe? After all, bogies are made of bacteria, viruses and dirt that get trapped by the little hairs and mucus in your nose.

Some argue that eating them might be good for us. The 'hygiene hypothesis' is a theory

that early exposure to germs and certain infections can boost the development of the immune system. But all of this has been difficult to prove; as you might imagine, it's hard to recruit enough volunteers for a proper study on bogie dining.

All in all, it's probably not a great idea. If your hands are carrying bacteria or viruses, the act of sticking them up your nose can lead to illness. And if you're the one that's carrying a bacteria or virus, you're more likely to spread it if you don't wash your hands afterwards.

So next time you or your toddler are tempted to snack on your nose greens, try to reach for a tissue instead – it's probably not worth the risk. *NM*



DANIEL HUTCHINSON, DOVER

WHY DO PEOPLE BELIEVE IN CONSPIRACY THEORIES?

In the wake of the US Capitol riot and the COVID-19 pandemic, conspiracy theories are running rampant. Whether it's the idea that the world is being run by Satan-loving paedophiles or that coronavirus is spread by 5G technology, for those of us for whom such claims seem outlandish and ridiculous, it is extremely difficult to understand why anyone would believe them. However, psychology researchers have uncovered a range of explanatory factors, from basic perceptual processes to emotional issues.

For instance, while all of us can be prone to seeing illusory patterns (such as a face in the clouds), a study led by Vrije Universiteit Amsterdam showed that this tendency is heightened among believers in conspiracy theories. This means they



Protesters marching against vaccinations in London 2020

are likely to see apparent connections between disparate events that the rest of us just don't notice.

Of course, many conspiracy theories make claims that are factually incorrect or they are based on fundamentally flawed logic. Unfortunately, believers in the theories are not only more likely to see illusory connections, research shows they are also less likely to have had the kind of education or have the critical thinking skills necessary to help them see the glaring holes in their wild theories.

At the same time, believers in conspiracies often have an inflated sense of their own intellectual competence – research led by the late Scott Lilienfeld at Emory University in Atlanta showed that in personality trait terms, believers tend to be lower in 'intellectual humility'. Ignorance combined with overconfidence creates a fertile ground for unsubstantiated beliefs to take hold.

There is also a powerful emotional component to conspiracy theory beliefs, which helps explain why they can be so difficult to challenge. Believing in a widely discredited theory – and feeling part of a community of fellow believers – can help to satisfy some people's need to feel special, according to research. Studies have also shown believers are also more prone to anxiety and a sense that they lack control – feelings alleviated by subscribing to a conspiracy theory being spread with such apparent conviction by others. **CJ**

GRACE PACKARD, EXETER

WHAT DOES A COMET SMELL LIKE?

The European Space Agency's Philae lander analysed the chemical makeup of the comet 67P/Churyumov-Gerasimenko. The main constituents were odourless water vapour, carbon dioxide and carbon monoxide. But there were also traces of particularly pungent (and toxic) substances such as ammonia (which smells like urine),

sulphur dioxide (burning matches), hydrogen cyanide (almonds) and hydrogen sulphide (rotten eggs). In 2016, Dr Colin Snodgrass, a researcher at the Open University, UK, commissioned The Aroma Company to recreate the unpleasant scent to be impregnated in promotional postcards. **AGu**

EMMA SMITH, HOLYHEAD

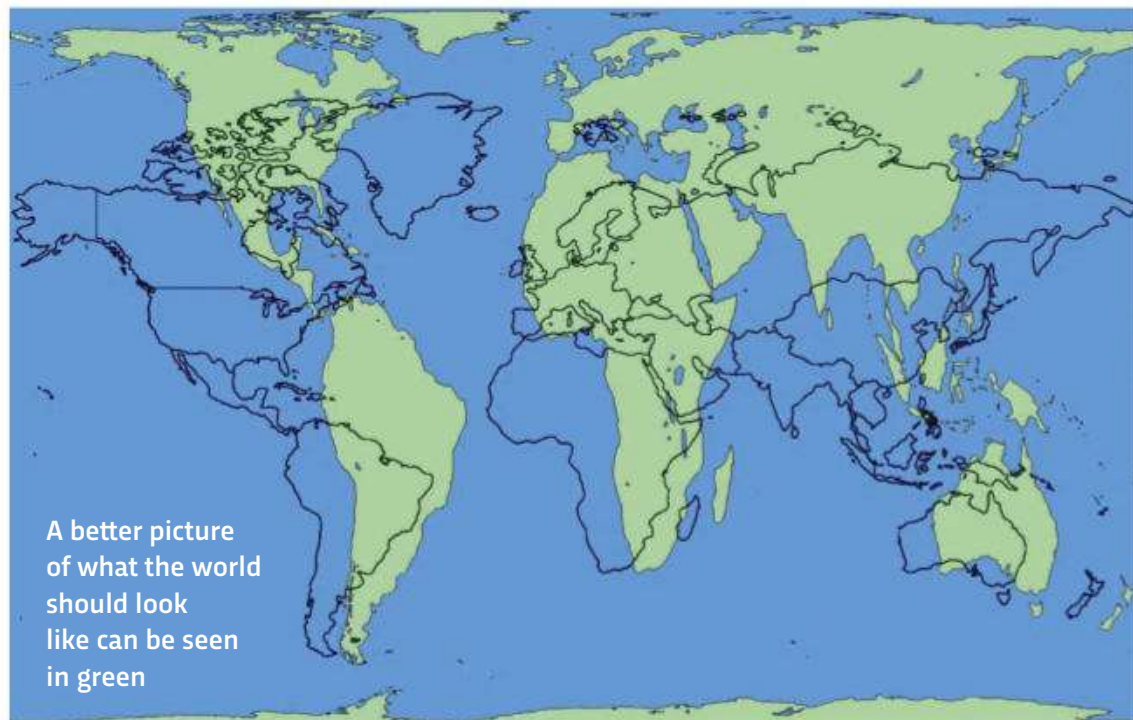
ARE MOST MAPS OF THE WORLD WRONG?

Every map ever printed is wrong, by definition. The job of a map is to provide a simpler representation of the world. A completely accurate map would need to be life-size. Worse, the Earth is round and paper is flat. Over small areas, the curvature isn't noticeable, but to unwrap the entire globe, you either have to stretch it or cut it to make it fit on a flat sheet. There are lots of different ways of doing this, but the Mercator projection, invented by Gerardus Mercator in 1569, is still the most widely used.

Imagine a glass globe with the continents painted on it. If you wrapped a sheet of paper into a cylinder around the equator and shone a light from

within, the landmasses would appear on the paper as shadows. This is the Mercator projection. On this map, north points to the top, and the coastline is the right shape, which makes it useful for navigation. But because the cylinder is open at the top and bottom, the poles can't be shown and north-south distances get increasingly stretched the further you get from the equator. Alaska looks as big as Brazil on a Mercator map, but is really a fifth the size, and Greenland appears 14 times too large.

Although digital maps could now display the Earth as a globe (Google Earth does this), most still use a version of the Mercator projection. **LV**



A better picture of what the world should look like can be seen in green

ALAMY, GETTY IMAGES ILLUSTRATION: DANIEL BRIGHT

TIM ELLAM, BATH

IS PINK A REAL COLOUR?



Light consists of electromagnetic waves, and colour depends on the wavelength. If colours were simply a naming scheme for wavelengths then pink is not one, because it is made up of more than one wavelength (it's actually a mix of red and purple light). If you took a laser and tuned it across the visible wavelengths, from infrared through to ultraviolet, you would not pass pink on the way.

However, colours are not simply names for wavelengths – colours merely label our perception of light, once it has passed through our eyes.

Our eyes contain sensors favouring red, green and blue, the signals from which are remixed in our brain. Our brains and eyes are smart enough to reliably pick out the mix of wavelengths we call pink, and give it all kinds of cultural associations. Considering all of this, it can be easily argued pink is a real colour. **JB**

DAMIAN BIENIAS, CROYDON

HOW DANGEROUS IS IT TO WEAR A TIE?

Despite being a symbol of smartness and professionalism, neckties may not be so good for your health. They can transmit bacteria from medic to patient more so than a shirt sleeve, and too-tight ties have also been found to increase pressure in the eye, possibly leading to an increased risk of glaucoma. Researchers in a small 2018 study found tight ties could also reduce blood flow to the brain by 7.5 per cent. However, the body has ways of safely counteracting this change in pressure. Things become more complicated when people have other health issues that lower their ability to cope with such changes, such as those who are obese, smoke or have high blood pressure. If you start to feel headachy, dizzy or nauseous, take the tie off. **SO**

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at bbcworldservice.com/crowdscience

HOW CAN SMART TECH TACKLE CLIMATE CHANGE?

The recent 2021 IPCC report declared a code red for humanity, with 2019's atmospheric CO₂ concentrations higher than at any time in at least two million years. Our only chance of averting irreversible climate change is to reduce our carbon, methane and nitrous oxide emissions to net zero. And one way we can achieve this is by making our technologies more sustainable.

For instance, we can embed artificial intelligence into our buildings and let them reduce power to lights, ventilation or lifts that are not in use.

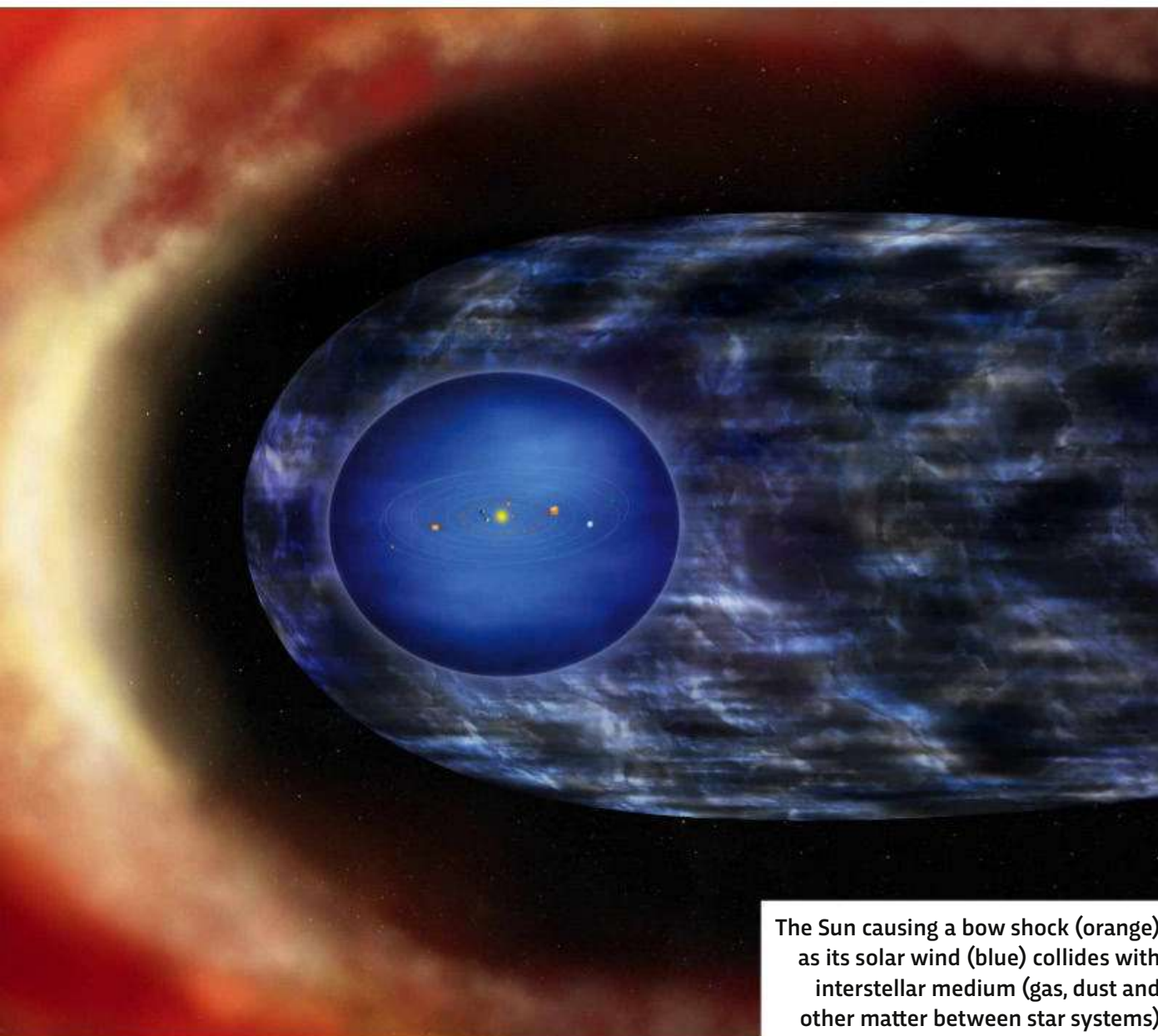
Zero-emission electric cars will also have AIs to assist our driving, making them safer and more efficient. Home energy storage solutions mean that power from solar panels can be

stored, bringing us towards a distributed power grid where all buildings contribute power as well as consuming it.

AI provides us with ever more accurate models of the environment and can also mitigate the risks of climate change, by simulating exactly where floods or storms may damage property. AI can enable smarter, more efficient agriculture, and instant analysis of planetary data so we can detect illegal deforestation, water extraction, fishing and poaching. Machine learning may even have the potential to invent new materials to create technology such as room temperature superconductors.

Put together, this tech could increase the chance of Earth's survival. **PB**





The Sun causing a bow shock (orange) as its solar wind (blue) collides with interstellar medium (gas, dust and other matter between star systems)

MALIA BARNARD, CARDIFF

DOES OUR SOLAR SYSTEM HAVE A WALL?

Yes and no. True, scientists sometimes describe the rise in temperature at the Solar System's 'heliopause' as a wall. This is the region of space where the 'solar wind' – the constant stream of mostly protons, electrons, and alpha particles emitted by the Sun – is no longer strong enough to push back the 'wind' of particles coming from distant stars. Here, the hot, tenuous solar wind plasma (ionised gas) gives way to the colder, denser 'interstellar medium' (ISM).

The heliopause marks the boundary between the Solar System and interstellar space – it is the edge of the 'heliosphere', the bubble of space in which the Sun's magnetic field and particle emissions dominate.

How large is this important boundary? Consider that one astronomical unit, AU, is defined as the average distance between the Earth and the Sun. The heliosphere lies at about 120AUs from the Sun in the direction facing the interstellar wind – and

in the opposite direction it extends to at least 350AU.

By deflecting 70 per cent of energetic 'cosmic rays', the Sun's heliosphere is crucial in protecting the Earth (and hence humans) from harmful interstellar radiation.

Launched in 1977, initially bound for Jupiter and Saturn, NASA's Voyager 1 and Voyager 2 spacecraft appear to have crossed the Sun's heliopause on 25 August 2012 and 5 November 2018, respectively. Instruments onboard Voyager 2 discovered that as plasma at the heliopause slows down, it becomes denser and the local magnetic field increases. Just beyond the heliopause, the temperature of the ISM is a staggering 29,700–50,000°C. This region has somewhat sensationally been dubbed the 'wall of fire'. This is misleading because, although it is incredibly hot, the plasma here is extremely diffuse; meaning the Voyager probes (or anything else for that matter) can easily pass through the heliopause completely unharmed. **AGu**

OLD WIVES' TALES...

DOES AN APPLE A DAY KEEP THE DOCTOR AWAY?

Apples are a decent source of fibre, vitamins, minerals and flavonoids (which may help to prevent cancer). But are they any better than fruit in general, and does daily consumption have a measurable health benefit?

Per 100g, apples have more fibre than melons, mangoes or grapes, and twice as much vitamin A as pears. But apples have less folate than blueberries and less vitamin C than oranges or bananas.

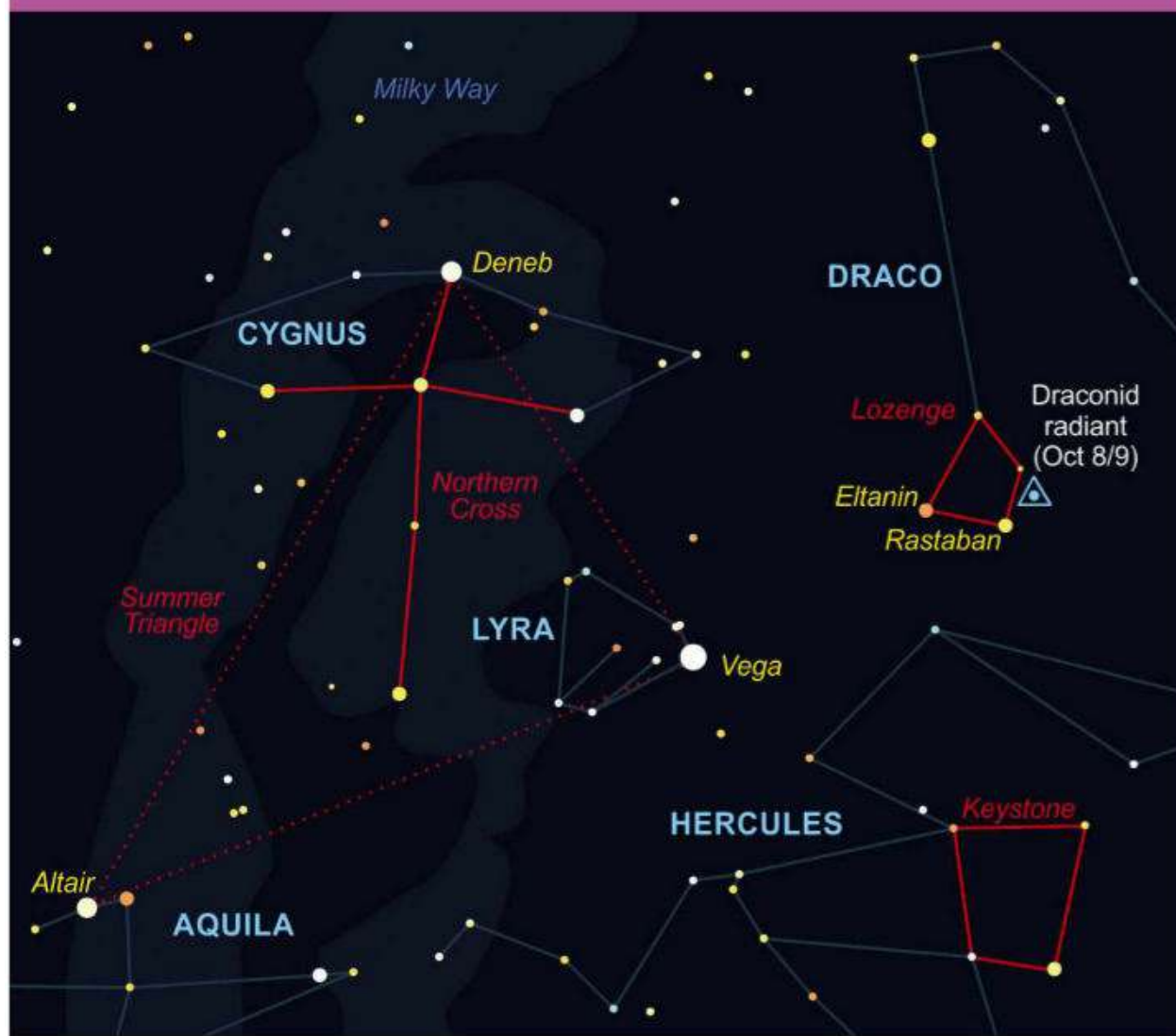
A 2015 study used diet survey data for 8,000 adults in the US and compared the number of doctor's visits, overnight hospital stays and prescription medicines, between apple-eaters and non-eaters. The study found that those who ate at least one apple per day (either whole, or as part of other foods) were slightly less likely to need a GP visit or medication.

Crucially, this difference disappeared once the researchers adjusted for socio-demographic and health-related characteristics. In other words, it is not that eating an apple a day means that you don't get sick, rather, the study found that healthy people tend to eat more apples. This might be because the apple-eaters were also making other lifestyle choices with a more direct effect on their health.

Ultimately, focusing on any one food for its unique health benefits is the wrong approach. A healthy diet includes a wide variety of different fruits and vegetables. **LV**



ASTRONOMY FOR BEGINNERS



HOW CAN I SEE THE DRACONID METEOR SHOWER?

WHEN: 7-11 OCTOBER

Meteor showers occur when Earth passes through a trail of debris that has been left behind by a passing comet or asteroid. As these remnants – mostly the size of a grain of sand – enter Earth's atmosphere, they create bright streaks across the sky as they burn up.

With two meteor showers, October is the perfect time to wrap up, grab a hot drink, and lie back to enjoy the show, preferably somewhere dark (it will take about 15 minutes for your eyes to adjust).

The Draconid meteor shower is visible between 7-11 October, peaking on the night of 8 October. Sometimes known as a 'minor' shower, it may only produce about 10 meteors an hour, although it has spewed out many more in the past. For instance, stargazers in 2012 noted several thousand per hour!

If that isn't enough to convince you to try your luck, the Draconids make an appearance early in the evening, as darkness falls from around 8pm. This is quite different from other meteor

showers, which often peak after midnight. The reason for this is that the radiant – the point in the sky where the meteors appear to burst from – is already high in the northern sky, in the constellation of Draco the Dragon. One easy way to navigate to Draco is to draw an imaginary line upwards through the stars Altair and Vega in the asterism known as the Summer Triangle. As night progresses, Draco will appear lower in the sky, eventually sitting below Vega.

The second meteor shower of the month is the Orionids on 21-22 October, where you can expect to see up to 20 meteors an hour. However, by then the Moon will be full, making fainter shooting stars a challenge to spot. The best time to watch this shower will be after midnight, looking slightly to the left of Orion, which can be sighted in the east to southeastern sky.

Meteors could appear anywhere in the surrounding area to the constellation, so keep your gaze wide! **NB**

WHICH IS THE BEST

Just how happy can a child make you? The answer, it turns out, could depend on where you live. At least that's according to a major study of 22 countries that compared the happiness of adults with and without children. By using a survey to score people's general happiness levels – rather than just asking about a parent's satisfaction with having children – researchers from the University of Texas concluded there was a significant 'happiness gap' between the two groups.

Which group was better off varied between countries, with parents in nations

ANNA CROSBY, DURHAM

DO ANIMALS GIVE EACH OTHER NAMES?

Once thought of as a uniquely human trait, research now suggests that other social species also dish out and respond to names. Green-rumped parrot parents give their chicks a 'signature call' or 'name', which is learned in the nest.

Dolphins learn their own, idiosyncratic 'signature whistle' from their mother, as well as recognising and remembering the 'names' of other dolphins too. These names are loaded with meaning – one study found that male dolphins respond more strongly to the whistles of consistently helpful allies than to those of more erratic aides. **HP**



GETTY IMAGES X3 ILLUSTRATION: PETE LAWRENCE

COUNTRY TO BE A PARENT?

such as the UK being more than 8 per cent less happy than non-parents on average. This gap widens to 12 per cent in the US.

However, this 'parental happiness deficit' doesn't occur everywhere. Parents in some countries – particularly in those nations with low fertility rates and more generous child benefit policies, such as paid time off and childcare subsidies – are significantly happier than non-parents. Such countries include Portugal (where parents are nearly 8 per cent happier than non-parents), Hungary (4.6 per cent) and Spain (3.1 per cent).



SOURCE: Parenthood And Happiness: Effects Of Work-Family Reconciliation Policies In 22 OECD Countries
ncbi.nlm.nih.gov/pmc/articles/PMC5222535/

QUESTION OF THE MONTH

KAMILA MAGMEDOVA, AGED 14

DO HUMANS HAVE A GENETICALLY INHERITED PREFERENCE FOR TASTE?

We do. Thanks to studies monitoring identical twins, and surveys of gene data from personal genomic companies, we know that there are genes that affect our sense of taste, our sense of smell, and even the reward centres in the brain. For instance, our likelihood of thinking that coriander tastes soapy is thanks to the variant of the odour receptor gene OR6AS that you inherit.

Genes can influence whether you can taste the bitter compound phenylthiocarbamide or not (about 30 per cent of Europeans have the variation of the taste receptor gene TAS2R38 that makes them 'taste blind' to this cabbage flavour). Even the extent to which your brain's reward centres respond to bacon could come down to DNA (blame your variant of CNTN5 if you're addicted to this meaty treat).

But our food preferences don't just come from our genes. We know that babies in the uterus will 'breathe' amniotic fluid – and that newborns prefer the taste and smell of compounds that their mothers ate a lot of in pregnancy.

And even though we're all genetically predisposed to be suspicious of bitter compounds – they're usually toxic to humans – most of us learn to tolerate, or even love, bitter things like coffee, chocolate or alcohol once we've discovered their fringe benefits. So your genes may have a lot of influence but they're far from the whole story. *EB*



WINNER

The winner of next issue's Question Of The Month wins **two Sharp GX-BT60 speakers**, worth £60. These ultra-light, portable Bluetooth speakers have 13 hours of playtime, are dust-proof and can survive being briefly immersed in water. Plus, with their True Wireless Stereo technology, you can pair the two speakers together for more volume and power.

sharpconsumer.uk/

EMAIL YOUR QUESTIONS TO QUESTIONS@SCIENCEFOCUS.COM



THE EXPLAINER

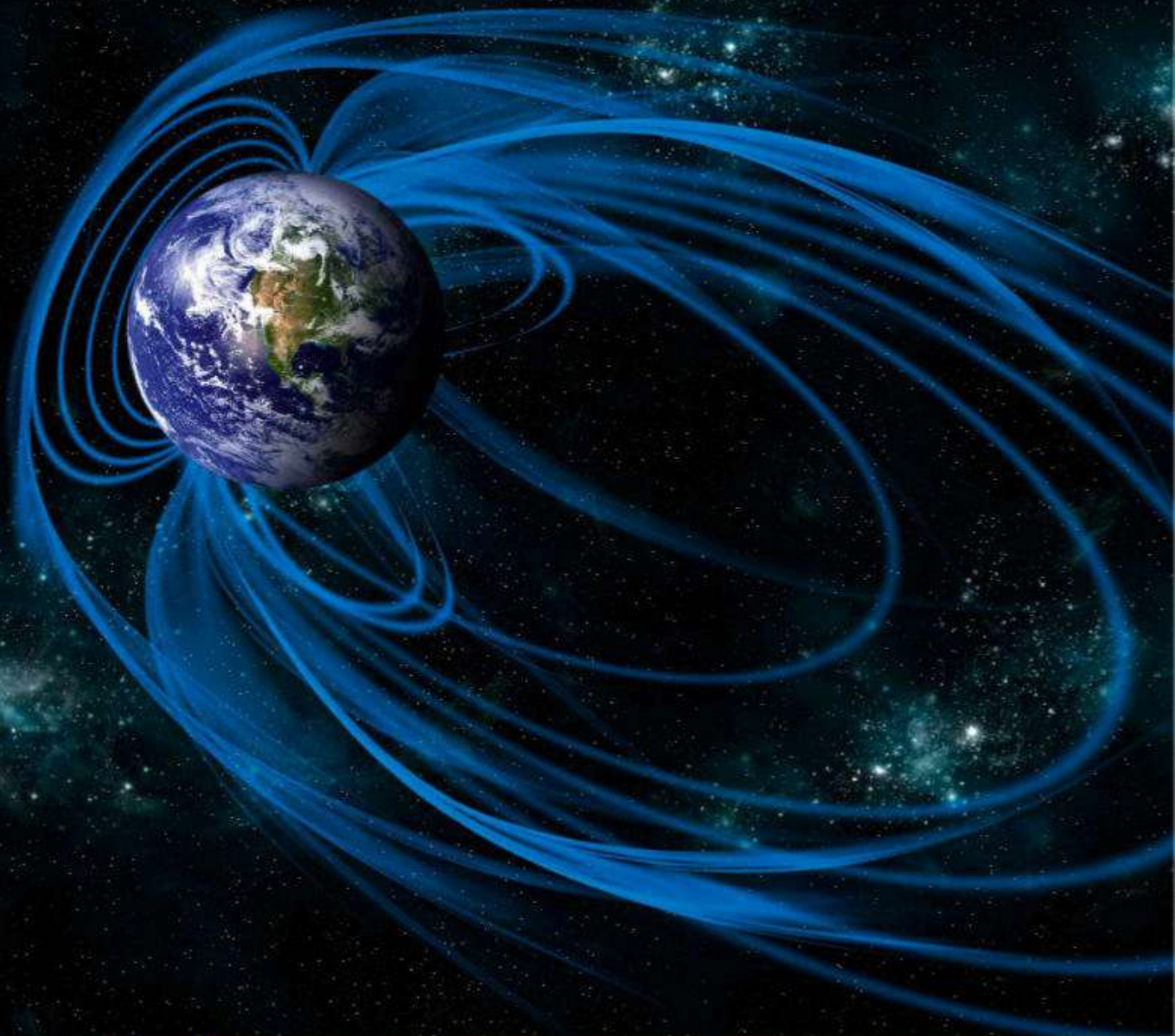
SHOULD WE BE WORRIED ABOUT EARTH'S MAGNETIC CORE?

WHAT CAUSES EARTH'S MAGNETIC FIELD?

Magnetic fields are generated by electric charges in motion. In a bar magnet, the moving charges are electrons orbiting in atoms. In the Earth, they are electrons ferried around by circulating currents of molten iron.

The details are not well understood. But, basically, hot material in Earth's outer liquid iron core expands, becoming less dense than its surroundings, and therefore rises. Cooling and becoming less dense, it should sink back down again. But the Earth's rotation prevents this. Consequently, liquid circulates around the core, and friction between its different layers charges them up – just like a plastic comb rubbing against a nylon sweater. It's these moving charges that generate the Earth's magnetic field.

The two requirements for planetary magnetism are therefore a liquid core and rotation. We know this because Venus, though roughly Earth's size, has essentially no magnetic field. The planet has a liquid core but rotates slowly – only once every 243 Earth days.

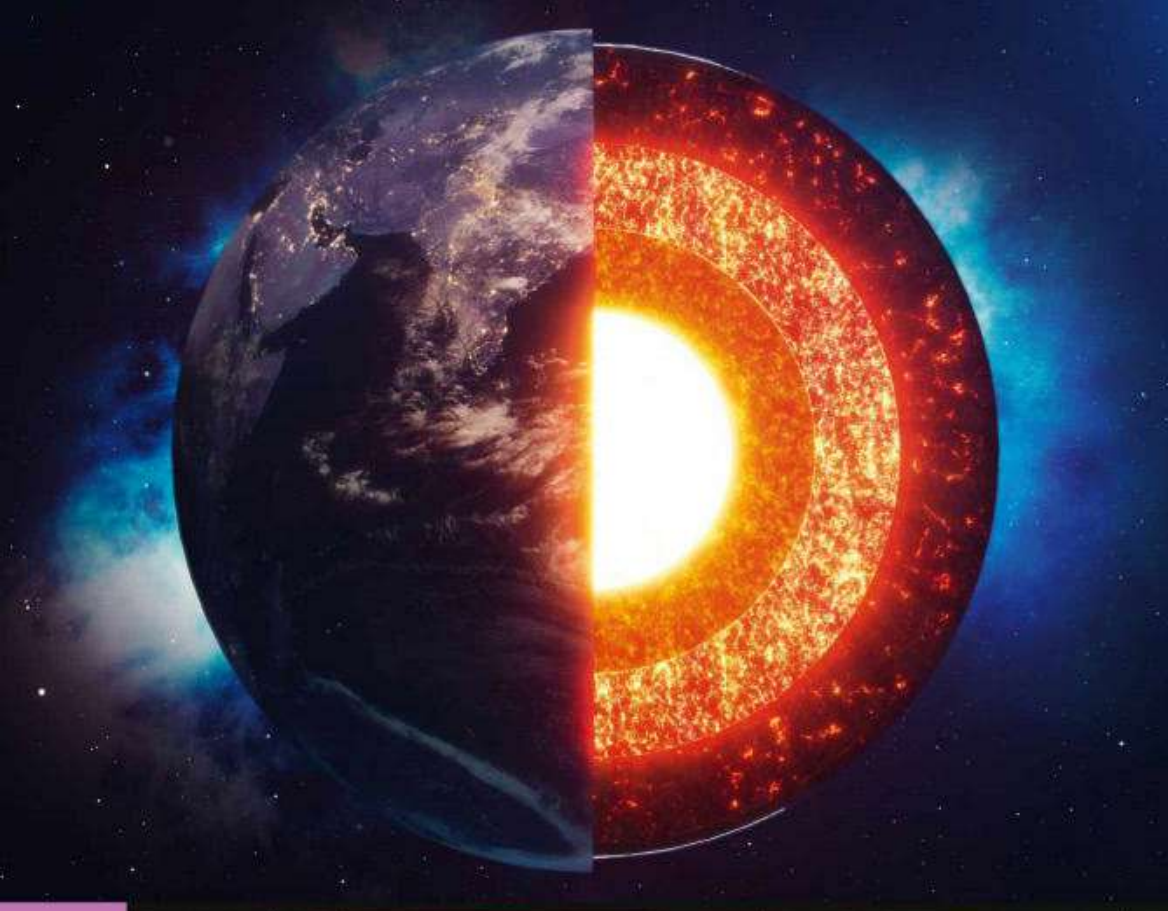


WHY DO EARTH'S MAGNETIC POLES MOVE?

Though the Earth's magnetic field is very similar to that of a bar magnet, with a north and south pole, it is not as stable because it is generated by complex processes inside the Earth. These cause the magnetic poles to wander.

Historically, the North Pole has moved at about 15 kilometres per year. But since the 1990s it has sped up, and now is moving at about 55 kilometres per year towards Siberia. It is speculation, but this might foreshadow a 'magnetic reversal' in which the magnetic north and south poles change locations. This has happened 171 times in the past 71 million years – and we are overdue a flip.

Models of the Earth's magnetic field based on satellite observations have shown that the present wandering is the result of a battle between 'blobs' of unusually intense magnetic fields deep inside the planet. As for the flipping of the Earth's magnetic field, nobody is 100 per cent sure why this happens.



HOW STABLE IS EARTH'S MAGNETIC FIELD?

The fact that the Earth's magnetic field depends on electric currents carried by molten material circulating in the planet's turbulent interior means it is inherently variable, as demonstrated by the present wandering of the magnetic north pole (the magnetic south pole is, surprisingly, not wandering as fast). But what is remarkable is that the magnetic field generated by such violent internal convulsions is relatively stable 99.9 per cent of the time. It is the stability of the Earth's magnetic field and the reliability of the protection it has provided, that has enabled life on Earth to persist for almost at least 3.8 billion years.



WHAT WOULD HAPPEN IF THE MAGNETIC FIELD DISAPPEARED?

Scientists discovered magnetic reversals by measuring the magnetic field on either side of mid-Atlantic ridges from which molten rock is extruded like toothpaste from a tube. As it solidifies, its crystals align along the direction of the Earth's magnetic field at the time, leaving a 'tape recording' of reversals.

Reversals are believed to take place over 1,000 to 10,000 years, during which time the field shrinks to zero before growing again with the opposite polarity. There were therefore times – maybe even centuries – when the Earth had essentially no magnetic field.

This is dangerous for life since the planet's magnetic field extends far into space and creates a protective bubble around Earth, shielding the planet's surface from the hurricane of particles of the Sun's 'solar wind' and higher energy 'cosmic ray' particles from deep space. Normally, these are safely funnelled down at the poles, creating the auroras. Without a protective field, such deadly radiation would increase the mutation rate of living cells, leading to cancers in animals. Nevertheless, life has weathered large numbers of such events before without being wiped out.



HOW DO ANIMALS USE THE MAGNETIC FIELD TO NAVIGATE?

Many creatures demonstrate remarkable feats of navigation. The suspicion has therefore arisen that they have some kind of magnetic sense, enabling them to detect the magnetic field lines between the poles. Pinpointing the mechanism, however, has proved difficult. But progress has been made this year by Japanese scientists investigating a process discovered many years ago. In the 1970s, Richard Blakemore, a graduate student in the US, observed single-celled organisms streaming in a fixed direction in a muddy pond and showed they were responding to a magnetic field. Biologists later discovered that such single-celled organisms contain tiny bags of magnetic iron oxide or iron sulphide.

Now, Noboru Ikeya and Jonathan Woodward at the University of Tokyo have shown that a magnetic field causes chemical changes that can affect cellular behaviour. They achieved this with the aid of a cellular chemical that fluoresces depending on the external magnetic field.

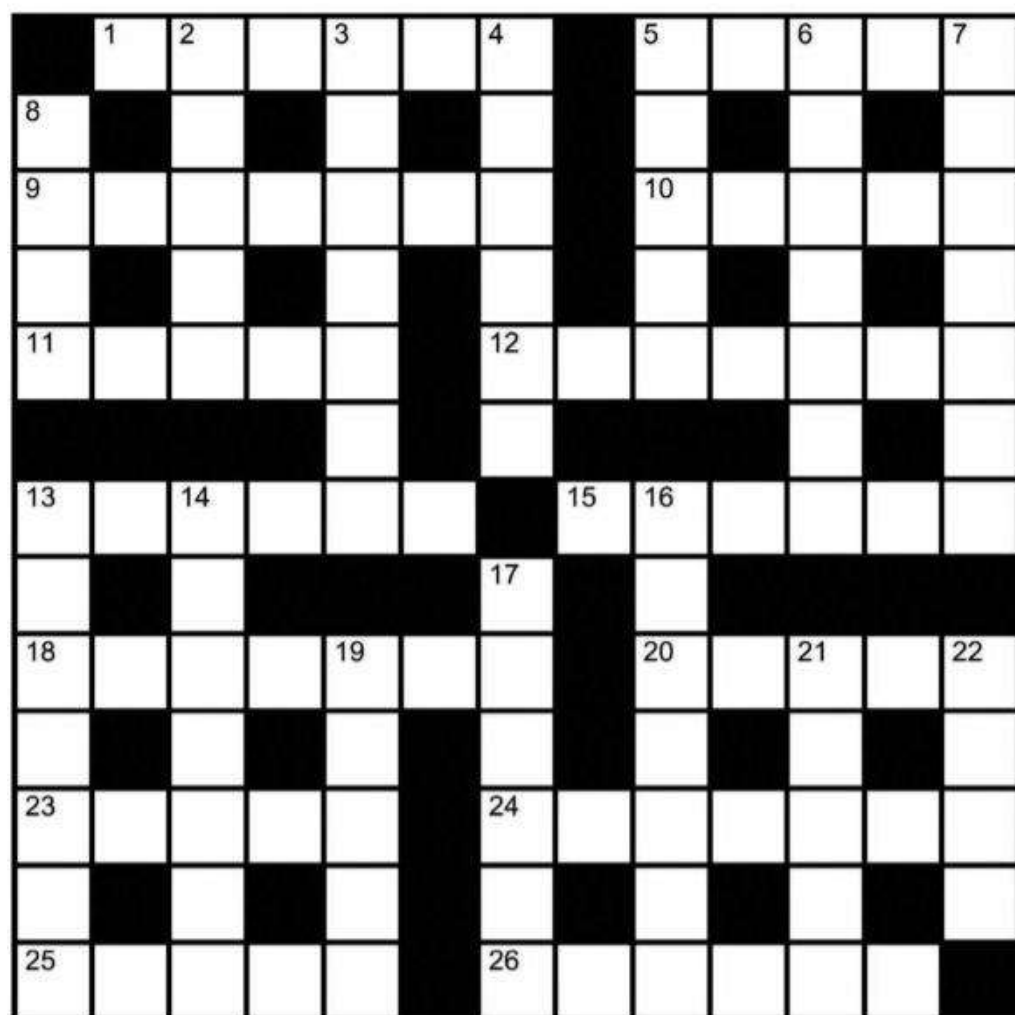
When they waved a magnet near cells, the chemical dimmed by up to 3.5 per cent.

by **MARCUS CHOWN**

Marcus is a science writer, broadcaster and author of *Breakthrough* (£9.99, Faber & Faber).

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

- 1 Mark, struck by drummer, say (6)
- 5 Heard directors were fed up (5)
- 9 Investigator is nasty about getting a student (7)
- 10 Jelly for crawler in charge (5)
- 11 Fool caught inside hill (5)
- 12 Treated a mad one, but it's benign (7)
- 13 Adapt medium, sick of DIY (6)
- 15 Coach let off in rush (6)
- 18 Charm of French illumination (7)
- 20 Horrify a quiet friend (5)
- 23 Big look around the house (5)
- 24 Digital audio file about cod in former time (7)
- 25 Pale, like a farm animal (5)
- 26 Creature is wild, not red (6)

DOWN

- 2 Deserve sticky end before ache (5)
- 3 Flavouring used by a flea (3,4)
- 4 Allow Harold to be mortal (6)
- 5 Support a couple (5)
- 6 Knock on the left in mutual understanding (7)
- 7 Impose detectives around gallery (7)
- 8 Very arduous, holding length (4)
- 13 Composed air about cake (7)
- 14 Treacherous woman left a husband behind food store (7)
- 16 A French idea about daughter not getting help (7)
- 17 Puts back gold in a daze (6)
- 19 Increased force, worn out (5)
- 21 Piece gets registered as seafood (5)
- 22 Overdue, chipping front off tile (4)

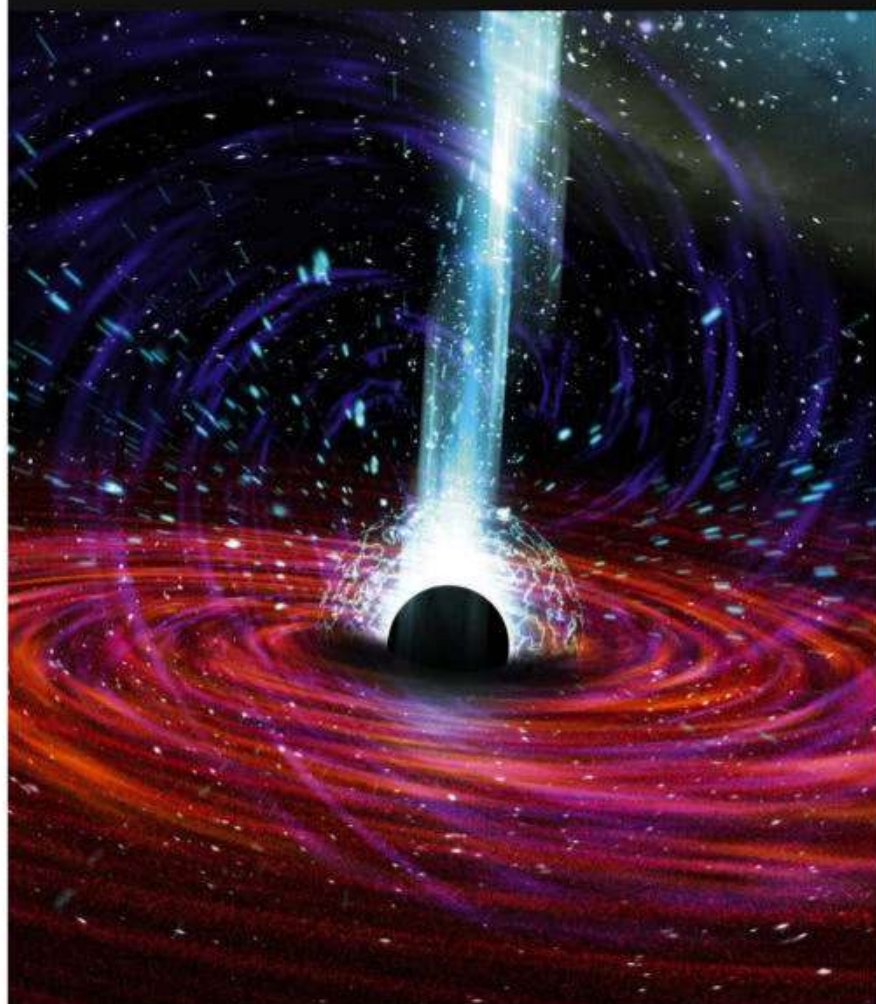
ANSWERS

For the answers, visit bit.ly/BBCFocusCW

Please be aware the website address is case-sensitive.

NEXT ISSUE

PRIMORDIAL BLACK HOLES



PLUS

THE WEIRD WORLD OF OCTOPUSES

Dive beneath the waves and enter the realm of these seriously smart molluscs.

MIGRAINES EXPLAINED

By expert Dr Katy Munro.

ON SALE 3 NOVEMBER

SF

GETTY IMAGES



TRY 3 ISSUES FOR £5*

When you subscribe to *BBC Sky at Night Magazine* today!

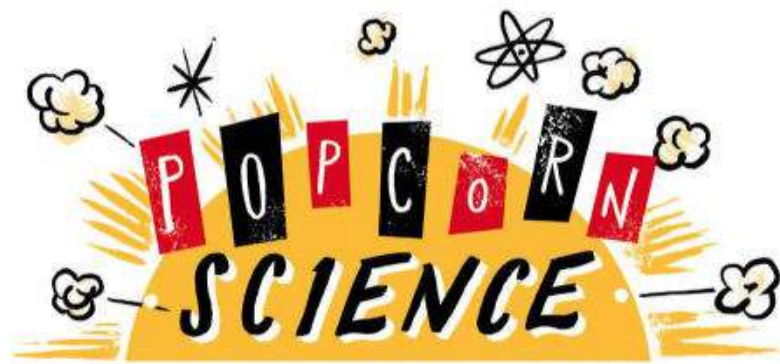
3 ISSUES FOR £5!

- ◆ Receive your first **3 issues for only £5*** – take advantage of our offer today!
- ◆ After your trial, continue to **save over 30% on the shop price** when you pay by Direct Debit
- ◆ **Expert advice** on getting the most from your observing every month
- ◆ **In-depth** features, stargazing guides and equipment reviews

Subscribe online at www.buysubscriptions.com/SKYHA21
Or call 03330 162 119† and quote SKYHA21

*All savings are calculated as a percentage of Basic Annual Rate. The UK Basic annual rate is £71.88 which includes event issues (issues charged higher than standard cover price) published in a 12-month period. This special introductory offer is available to new UK residents via Direct Debit only and is subject to availability. Offer ends 31 December 2021. The magazine used here is for illustrative purposes only, your subscription will start with the next available issue. After your first 3 issues, your subscription will continue at £22.97 every 6 issues thereafter, saving over 30% off the shop price. Full details of the Direct Debit guarantee are available upon request.

†UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 9am to 5pm.



Is regeneration possible?

Doctor Who makes it look so easy. Is there hope for the rest of us?

by STEPHEN KELLY



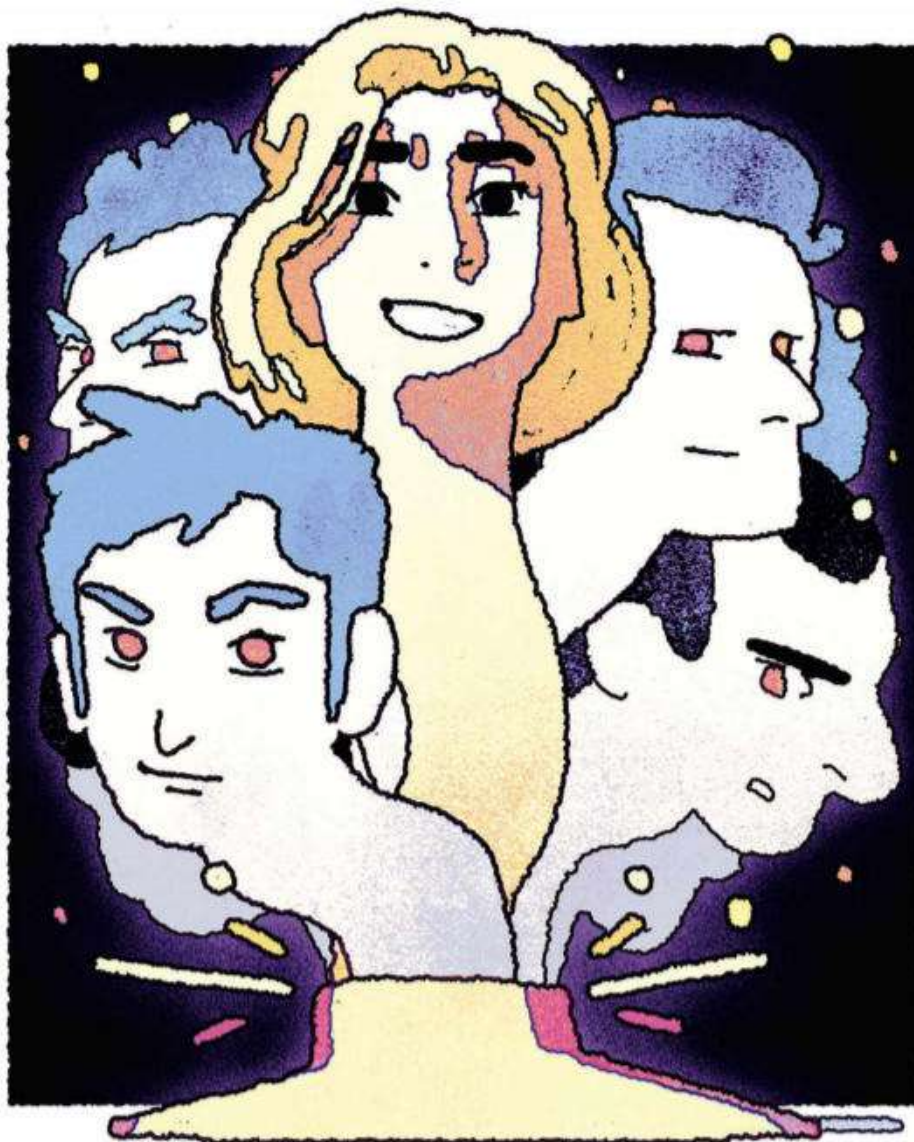
One of the main reasons why *Doctor Who* – both the show and the character – has survived so long is the concept of regeneration. Every time the Doctor dies, the character is renewed – their cells rewritten, their wounds repaired, their severed limbs regrown. It's a process that Jodie Whittaker's 13th Doctor will be undergoing soon, with her final series due to air on BBC One this October.

The idea of a regeneration so extreme that it can transform one person into another is, of course, a bit fanciful. But the basic tenets of regeneration (extending life, regrowing body parts) is science fact in the animal kingdom – and one day, it might be for us too.

"I'm old enough to say, 'never say never,'" says Alejandro Sánchez Alvarado, a molecular biologist at the Stowers Institute for Medical Research in Kansas. Alvarado studies the regenerative abilities of planarian flatworms. Remember that episode of *Doctor Who* where a new David Tennant grows out of the 10th Doctor's severed hand? Well, flatworms do that for fun. "They can be sliced and diced in every imaginable way," says Alvarado, "and each piece will regenerate a complete animal."

There are other examples too. Deer can regrow their antlers exactly as they looked before. The spiny mouse can have its skin torn off by a bird and grow it back. Salamanders and newts can repair limbs and organs. Snails can lose an eye nearly as complex as a human's and regenerate a new one. Some species of Hemichordate, a group of marine invertebrates, can spring a new head after decapitation.

These animals share some factors. They tend not to scar over when injured, meaning



the wound epidermis can remain in contact with the underlying tissue. They tend to have an abundance of stem cells and/or cells that display some degree of plasticity. But what leads to certain animals developing those attributes? How do they use them to regenerate? And why can certain animals regenerate limbs and humans can't? "Those are the kinds of questions that we're struggling with," says Alvarado.

Humans do have some regenerative abilities. The liver can repair itself. Our blood system is constantly regenerating. And there are cases of people regrowing the tops of severed fingertips (if the wound is left open). "You have to lose

your digit without losing the base of your fingernail," says Alvarado. "The base has stem cells that can get activated to produce not just the nail but also connective and bone tissue."

Such regenerative quirks suggest that humans once had the ability to regenerate, but it's now dormant. "The question is," asks Alvarado, "if we had it, why did we lose it?" Theories range from regeneration being incompatible with intelligence to it being an evolutionary trade-off to suppress our rates of cancer. But Alvarado is optimistic it can be reactivated. Imagine, for example, being able to regrow a foot after it's been amputated. Or repair a heart damaged by cardiac arrest.

"The fact that our molecular toolkit is almost indistinguishable to other vertebrates that can regenerate means it should be possible to engineer a means to introduce the ability of certain tissues to restore themselves. That, I think,

is perfectly feasible! We'll probably see that in the next 30 to 40 years." More than enough time to also build a phone box that travels through time. **SF**



VERDICT

We can't do it now, but medical science might just allow us to regenerate in the near future.

by STEPHEN KELLY (@StephenPKelly)
Stephen is a culture and science writer, specialising in television and film.

BBC
Science Focus
MAGAZINE



All the latest ideas, discoveries & big questions answered...

Install the official *BBC Science Focus Magazine* App today and get instant access to the current issue when you subscribe. With each new issue, you'll get the lowdown on the latest discoveries and big breakthroughs affecting our future.

SEARCH *BBC SCIENCE FOCUS MAGAZINE* IN THE APP STORE





Product of the environment

When polar ice melts, it harms habitats as far away as Asia and Africa. In 2022, conservationist (and Christopher Ward Challenger) Tom Hicks will lead an expedition to the North Pole to measure ice melt rates for the David Shepherd Wildlife Foundation (DSWF). On his wrist will be the C60 Anthropocene GMT. Able to monitor two time zones at once, waterproof to 600m and with a sapphire dial that recalls polar ice, it can withstand whatever the Arctic throws at it. And with five percent from the sale of each watch going to DSWF, it's playing its own part in the fight against climate change.

 **Christopher Ward**

Ingeniously English.
Unsurprisingly Swiss.

christopherward.com